TAMPERE UNIVERSITY OF TECHNOLOGY

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DEVELOPING A SYSTEMATIC MODEL FOR EARLY SUPPLIER INVOLVEMENT IN NEW PRODUCT DEVELOPMENT

Master of Science Thesis

Prof. Saku Mäkinen has been appointed as the examiner at the Council Meeting of the Faculty of Business and Technology Management on November 4th, 2015.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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This master's thesis discusses the practices of involving suppliers to a buying company's new product development projects. The objective of this research was to discover the factors that influence the need and form of early supplier involvement (ESI) and to develop a systematic model consisting of activities and considerations for managing ESI in new product development for a case company. The theoretical part discusses product development and sourcing and early supplier involvement in new product development.

The research was carried out as action research for the case company' sourcing department that was in the process of creating and developing systematic ESI practices based on a new sourcing strategy that was introduced during the research process. The research took place during a total of eight months when the researcher worked as an employee of the case company. Semi-structured interviews and workshops were conducted to gather qualitative data making this thesis a multiple qualitative method study. The data was gathered from cross-functional sources and several key stakeholders were involved in the research. Additionally, material was gathered by informal discussions, participating in two new product development projects at their early phases and accessing the case company's internal databases.

As a result of this master's thesis a systematic model was created for the case company. The model includes steps, related processes and considerations that should be carried out and acknowledged in terms of managing ESI during a product development process. The model covers activities and considerations taking place before involving a supplier, when selecting a supplier for involvement and when collaborating with a supplier. The case company's goal of improving collaboration between sourcing, R&D and suppliers was also supported by the change driving nature of action research. For academics this study offers a literature review and summary about the factors that should be considered when managing or thinking about establishing systematic practices for managing ESI in new product development on the operational project level. Additionally, the process of developing ESI practices for a company with a rather special high mix – low volume context is described with supplier perspective included.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tuotantotalouden koulutusohjelma

PIIRAINEN, JUKKA-PEKKA: Systemaattisen mallin kehittäminen toimittajan varhaiseen osallistumiseen uuden tuotteen kehityksessä
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Tämä diplomityö käsittelee toimittajan varhaista osallistumista ostavan yrityksen uuden tuotteen kehitykseen sekä siihen liittyviä käytäntöjä. Tutkimuksen tavoitteena oli selvittää tekijät, jotka vaikuttavat toimittajan varhaiseen osallistumisen (ESI) tarpeeseen ja muotoon sekä kehittää kohdeyritykselle systemaattinen malli, joka koostuu ESI:n hallintaan liittyvästä toiminnasta ja huomioitavista asioista. Teoriaosuus käsittelee tuotekehitystä, hankintaa ja ESI:ia uuden tuotteen kehityksessä.

Tutkimus toteutettiin toimintatutkimuksena kohdeyrityksen hankintaosastolle, joka oli luomassa ja kehittämässä systemaattisia käytäntöjä toimittajan varhaiseen osallistumiseen pohjautuen uuteen hankintastrategiaan, joka esiteltiin tutkimusprosessin aikana. Tutkimus sijoittui kahdeksan kuukauden ajanjaksolle, jolloin tutkija työskenteli kohdeyrityksen työntekijänä. Tutkimusmateriaalin keräämisessä käytettiin useampaa laadullisen tiedon keräämisen menetelmää: puolistrukturoituja haastatteluita ja työpajoja. Tutkimusmateriaali kerättiin osasto- ja organisaatiorajat ylittävistä lähteistä osallistaen useat keskeiset sidosryhmät tutkimukseen. Lisäksi materiaalia kerättiin epämuodollisilla keskusteluilla, osallistumalla kahteen alkuvaiheessa olevaan tuotekehitysprojektiin sekä kohdeyrityksen sisäisistä tietokannoista.

Diplomityön tuloksena kehitettiin systemaattinen malli kohdeyrityksen tarpeisiin. Malli sisältää vaiheet, oheisprosessit ja huomioitavat asiat, jotka tulisi tiedostaa hallittaessa ESI:ia uuden tuotteen kehityksessä. Malli kattaa aktiviteetit ja huomioitavat asiat ennen toimittajan osallistamista, valittaessa osallistuvaa toimittajaa ja tehdessä yhteistyötä toimittajan kanssa. Toimintatutkimuksen muutosta edistävä luonne tuki kohdeyrityksen tavoitetta parantaa yhteistyötä hankinnan, R&D:n ja toimittajien välillä. Akateemiselle yhteisölle tutkimus tarjoaa kirjallisuuskatsauksen ja yhteenvedon tekijöistä, jotka tulisi huomioida hallittaessa tai luotaessa käytäntöjä ESI:iin. Lisäksi työssä kuvataan käytäntöjen luomisprosessia kirjallisuudessa vähän tarkastellussa high mix – low volume –kontekstissa huomioiden myös toimittajien näkökulma.

PREFACE

I cannot express enough gratitude towards my supervisors and project team who made it possible for me to delve into the core of strategic sourcing, product development and collaboration across company borders. I am deeply grateful for all the support and guidance I received in the process of working on this thesis. Thanks to all participants of the research for encouragement, input and commitment. I would also like to thank professor Saku Mäkinen for guidance. Special thanks to my family who have always made it possible for me to be the best I can be and to Ella who supported me throughout the project. This thesis concludes my master's studies at TUT where I experienced unforgettable times.

Future appears intriguing to say the least.

Helsinki, April 7th 2016

Jukka-Pekka Piirainen

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ABBREVIATIONS AND NOTATION

BOM	Bill of materials
DFx	Design for x, where x can be for example M = manufacture or A = assembly
EMS	Electronic manufacturing services
ESI	Early supplier involvement
FMEA	Failure mode and effect analysis
IPDS	Integrated product development and sourcing
IPR	Immaterial property rights
LTCC	Low temperature co-fired ceramic
NDA	Non-disclosure agreement
NPD	New product development
PCBA	Printed circuit board assembly
PIC	Product inventory cost. Cost of materials + labor + overhead
RFQ	Request for quotation
R&D	Research and development

1. INTRODUCTION

1.1. Background and motivation

Companies are not alone in with their efforts to develop and introduce new products to the market. The ever intensifying global competition and increasingly demanding customers set strict price, time and quality pressures to companies and product development. Facing this competition, companies have followed the trend of focusing on their core competences while outsourcing their non-core capabilities and functions. (Prahalad & Hamel 1990.) As companies outsource they become increasingly dependent on other companies forming supply chains and networks that as a whole deliver value to the end customer (Wynstra et al. 1999). Not only single companies compete against their immediate competitors but supply networks compete against each other. Outsourcing of manufacturing and design efforts also poses challenges for companies who develop new products since collaboration needs to be closely coordinated not only within a company but across company borders (Frohlich & Westbrook 2001). Successful supplier involvement can help companies remain competitive (Handfield et al. 1999). Hence the suppliers have an increasingly important role as experts in their own areas increasing the importance of supplier collaboration during product development projects. Consequently, the role of sourcing as a function of a company has become increasingly strategic and important for the performance of a company (Gottfredson et al. 2005). Now key tasks for sourcing include operating as a connector between research and development (R&D) and suppliers as a participant in new product development project as well as selecting fitting suppliers for collaboration, managing supplier relationships and driving supplier development (Wynstra 1999; Van Echtelt et al. 2008).

Companies have started to see that involving the suppliers early to new product development may offer significant benefits (Ragatz et al. 2002). However, managing ESI has proven to be a challenging task as it requires suitable internal and external coordination of activities within a company and between companies as well as selecting the right suppliers for collaboration. Additionally, different company contexts require different approaches.

This master's thesis deals with the previous issues and topics and it was made as an assignment for a case company. The potential in involving the suppliers early in new product development was also identified in the case company as it did not have systematic practices for managing early supplier involvement in new product development projects. The case company has long traditions as a high-tech, R&D driven

company with several product lines, business segments and global operations. The company operates in high mix - low volume model. The company's products are include a variety of technologies such as different mechanical and electronic parts. The core competence parts the company manufactures themselves but other than that it mainly relies on the suppliers. Accordingly, the company has a high number of suppliers in mechanics, electronics and electronic manufacturing services (EMS). The suppliers are of different sizes and backgrounds. It is typical for the company's products to have long life-cycles, numerous product applications and demanding product requirements. Product development follows a concurrent engineering process with several concurrent process modules meaning that numerous people participate in the process simultaneously with their own effort. Previous literature about ESI is insufficient in studying ESI in high mix – low volume context as most of the studies are in the context of high volume, mature industries.

The research took place at a time when major changes regarding the sourcing organization were made and on the other hand the product development process had quite recently been renewed. During the research process the company's sourcing department introduced and received top management approval for a new sourcing strategy which would guide the sourcing department towards becoming a strategic function that enables competitive advantage and supports value creation to the customers. As a means to achieving the goal, early supplier involvement was included in the strategy as one of the corner stones. The goal in early supplier involvement endeavors was to provide R&D with the support of capable suppliers. The thesis project was carried out as a part of implementing the new strategy.

1.2. Research objectives and questions

The objective of the research is to create a systematic model for clarifying the activities and things to take into consideration in managing early supplier involvement in new product development projects at the case company. The case company has two separate business areas with several business segments within those areas. The systematic model is required to fit the needs of both business areas as both areas follow the same product development process. The overall long-term goal for the case company is to drive competitive advantage by establishing the ESI practices within the company and with the key suppliers. Additionally, the research attempts to contribute to theory by gathering the factors that influence the need for ESI and the form of ESI. Additionally, studying ESI in high mix-low volume business and describing the model development process strives to make a minor contribution to the academic community and ESI literature which typically revolves around mature high volume business. However, the main focus is in serving the needs of the case company instead of presenting a highly generalizable model to serve the purposes of several companies and industries. The corresponding main research question and sub-questions are presented in figure 1.1.

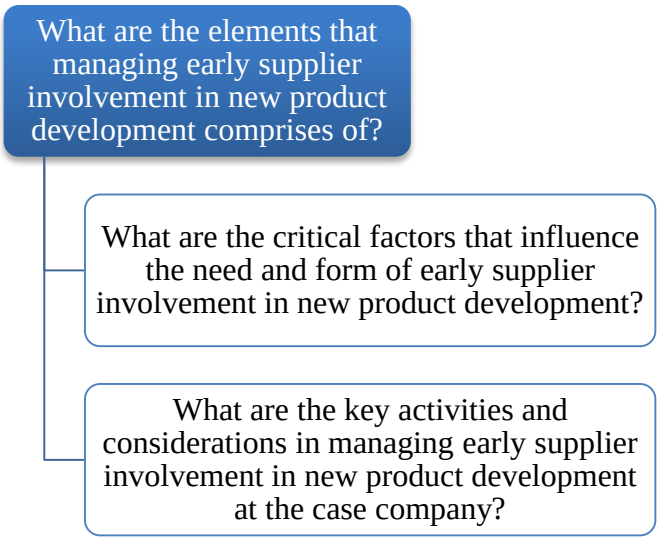


Figure 1.1 *The research questions of this study*

The first question deals with the issues that need to be taken into account regarding each activity in order to come to a conclusion about the most suitable approach. The first question will be answered through gathering the influencing factors from literature. The second question can be considered as finding out the main activities or building blocks for managing ESI in practice in a way that the project specific influencing factors are taken into account. The second question will be answered through the research process by iteratively mirroring theories to the data gathered from the case company. Besides these goals it was important that the researcher would increase ESI awareness and induce cultural change at the case company by engaging relevant stakeholders as a part of the project.

In literature ESI is also related to innovation activities where the goal is to involve suppliers into joint innovation projects to commercialize new technology. In this study ESI refers to design collaboration activities that take place during the company's own product development process instead of innovating with other companies and then handing the new technology over to a product development project. Innovating with the suppliers is therefore ruled out of the scope of this research although suppliers' innovative capabilities are of interest.

1.3. Research methods and process

This research was conducted for a case company and the researcher was able to participate in the activities of the company as an employee and member of the organization. The research process can be described as iterative action research which consisted of continuously learning about the company, its practices, product development process and projects, gathering ideas from literature and taking them into consideration in the research process, involving stakeholder in the creation of new practices and driving change. Theoretical background was covered by gathering fitting

literature that best supports understanding the phenomena that revolve around ESI and the case company's context. Semi-structured interviews and workshops acted as solid methods for gathering qualitative data and for involving the case company's employees in the project in addition to having informal discussions with various members of the organization. Also the suppliers were involved in developing the practices through interviews and workshopping. The researcher also participated in two product development projects in order to consider ESI in practice in those projects and to generate an understanding of the practical challenges.

The researcher had two instructors from the case company: head of sourcing and development manager of mechanical design. Additionally, the researcher had a project group to present findings to and receive feedback from as well as a steering group to oversee the project every two months. All of these supporting entities consisted of representatives of sourcing and R&D which highlights the intent of cross-functional commitment and collaboration regarding ESI.

The research process for this project started with interviews in June of 2015 and they were carried out during two months. The rest of the research took place during six months beginning from October 2015. A research needs to be connected to its context since same or related topics have been studied earlier. As stated by Saunders (2009, p. 98), by the means of discussion and referencing this previous literature, insight and support can be sought for carrying out a new research. Based on the research questions and objectives suitable literature should be gathered and reviewed to develop a comprehensive understanding of related previous research and the position of this study in it. (Saunders et al. 2009, p. 98.) This research was put into context in its field of study by conducting a review of literature related to themes such as new product development, early supplier involvement and sourcing. Literature was gathered throughout the research process but the majority was gathered during the summer and October of 2015. The literature mainly consists of commonly cited scientific journals and books. Also more recent work with less citations was included to provide fresh viewpoints. In literature the terms sourcing, purchasing, procurement and buying are used rather interchangeably to refer to the department that is responsible for managing supplier relations. This study refers to sourcing as a strategic function of a company while purchasing here refers to the department that makes the operative purchasing transactions. The research methods and process is described in more detail later in this study.

1.4. Structure of the thesis

This study follows a typical and commonly accepted structure for a scientific paper (Saunders 2009, p. 531). The full structure of the study is presented in figure 1.2.

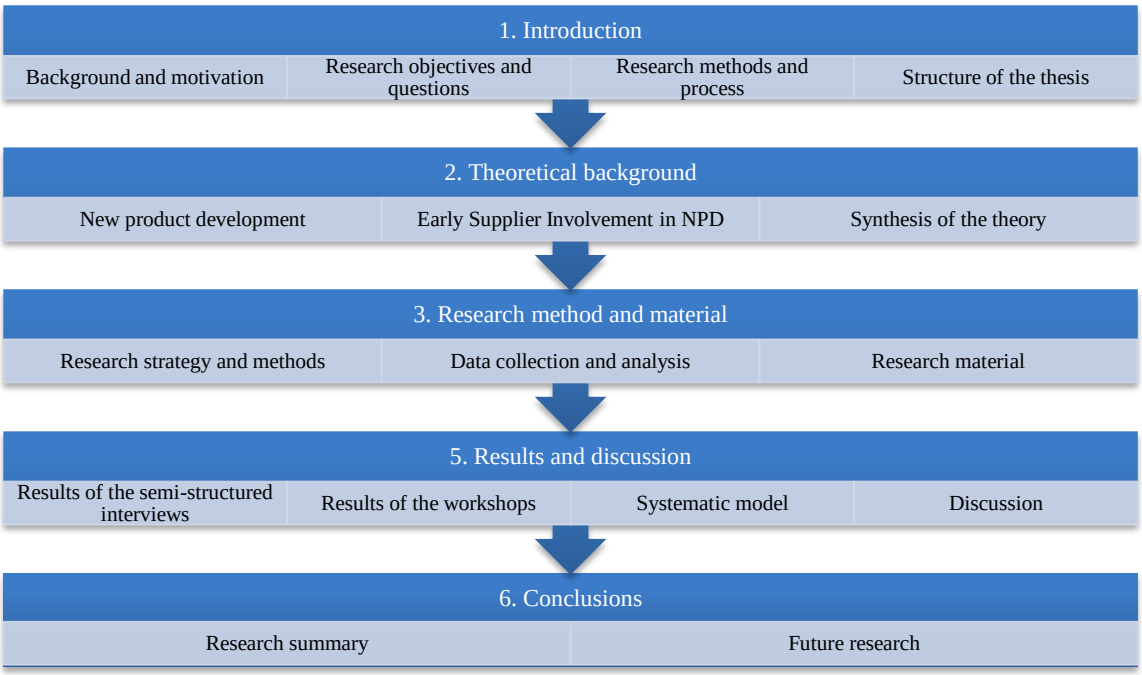


Figure 1.2 *The structure of the thesis*

After this introduction chapter the theoretical background is presented. In the theoretical background section new product development is briefly covered followed by a deeper look into early supplier involvement in new product development. As a part of this, the role of sourcing in new product development is also covered. At the end of the theory part, a synthesis of the theoretical background is provided in order to have a starting point and preliminary findings for the empiric part of the research. The synthesis consists of the factors that influence the need and form of ESI. Next the research methods and material are discussed in chapter three. First the formulation of the research strategy and method selections are described in detail followed by descriptions of how the semi-structured interviews and workshops were conducted and analyzed. In chapter five the results of the interviews and workshops are presented in narrative form supported by summarizing and categorizing figures. Next the final result of the study, the systematic model for ESI is presented as well as discussion about the results of the study. Last, in chapter six the conclusions are presented including summary of this research and suggestions for future research.

2. THEORETICAL BACKGROUND

In this chapter the theoretical background for the study is presented. The topics have been chosen in a way that best provides support understanding the context of the case company and the fit of ESI to it. The aim of the theoretical background is to go through the literature to discover theories that would be adaptable to the case company and to find out things that have an impact on how ESI should be managed. At the end of the theoretical part, a summary of the influencing factors to be considered when making decisions about the need and form of ESI at a company are presented.

2.1. New product development

In order to understand the context where early supplier involvement takes place one first needs to understand new product development. New product development can be defined as *"the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale"* (Krishnan & Ulrich 2001). Product development is a critical function of many companies since new products increasingly act as the center of competition and it may determine the competitive success or failure of a company. Additionally it may serve as a source of competitive advantage. (Brown & Eisenhardt 1995, p. 343-344.)

2.1.1. New product development as a process

New product development can be seen as a process with distinct phases. Although several different process models have been presented in literature the common steps are rather similar. The generic phases of product development process are presented in figure 2.1.

Figure 2.1. *The generic phases of product development process (Monczka 2000, p. 6)*

The process starts with generating ideas that could be turned into a product. The selected ideas are then assessed in terms of their technical feasibility followed by generating a concept of the product. In the product design phase the concept is developed into a product. The potential product designs are made into prototypes and tested until finally coming to a decision about the final design. After that the product goes into full scale production. (Monczka et al. 2000.)

It has been found that approximately 80% of the total costs of a product are already locked in and determined by the design decisions at the early phase of product development while the actual design work in the early phases causes only 5-8% of the total product development costs (Ragatz et al. 1997, p. 191). As illustrated in figure 2.2 as the product development process progresses the flexibility in design is reduced while the costs of making changes to the design increase. Therefore it is beneficial to avoid late design changes and instead aim to do the required design changes as early as possible and design according to the requirements. This principle can be summarized as doing it right the first time.

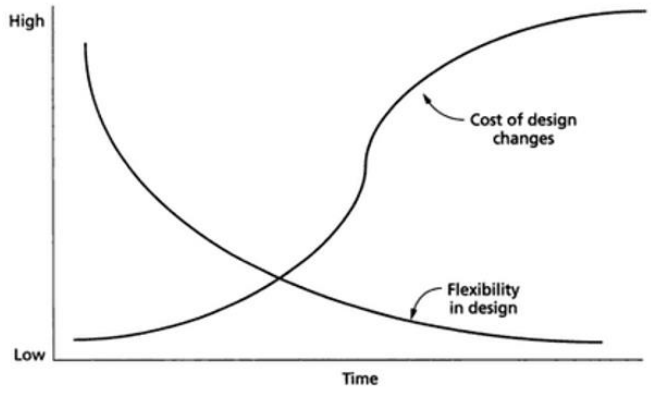


Figure 2.2. *The effects of time to design flexibility and cost of design changes in NPD (Monczka et al. 2000, p. 6)*

A popular way to manage the NPD process in practice is to utilize some sort of stage-gate process where the process is divided into pieces by setting gates between them. Decisions regarding proceeding (go or no-go) are made at the gates while during the stages the process is advanced and information is gathered to be able to make the decision at the gate. (Cooper 2008.)

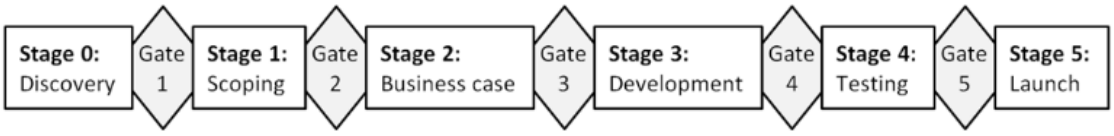


Figure 2.3. *The stage-gate process model (adapted from Cooper 2008)*

The stage-gate process offers a structured way to plan ahead in product development projects but it has its limitations since it forces to stick with the scheduled plan and to have the required maturity achieved when arriving at a gate. Therefore strict stage-gate processes might not be suitable for highly uncertain projects as it may bind creativeness when in fact more flexibility is needed. Under these circumstances the stage-gate model has received criticism. (Cooper 2008.)

2.1.2. Concurrent engineering

Unlike the development process presented in the previous section, product development is seldom a linear process. Moreover, in organizations it often requires the input of various people to successfully develop a product. Under time pressures companies are trying to reduce their product development time by having several people work on their own part of the development task simultaneously and proceeding with incomplete information. (Terwiesch et al. 2002, p. 402). This concept is called concurrent engineering (Yassine & Braha 2003, p. 165).

Concurrent engineering can be seen as a set of principles aiming at reducing development times, improving quality and achieving lower costs from development to production. This can be achieved by taking into account the requirements of the participating stakeholders already at the early phases of development. Therefore it is important that the critical information is available when necessary which means that the participants in the concurrent engineering process need to effectively communicate and share information with each other. (Yassine & Braha 2003, p. 165.) Concurrent engineering therefore consists of overlapping activities instead of finishing one activity before starting another. A concurrent engineering process can therefore be considered as a more flexible model compared to the stage-gate model since it allows for more uncertainty before moving on in the process.

Although there are several benefits in concurrent engineering, it is a challenging task to coordinate it since project schedules are tight, information becomes available gradually and many stakeholders may be included (Terwiesch 2002, p. 402). Yassine and Braha (2003, p. 166) presented four principles that are typical to concurrent engineering making it challenging to manage. First, concurrent engineering is typically highly iterative as information and requirements become clearer as the development process progresses. Based on this information the designers may have to iteratively translate the requirements into product specifications and make changes to the design. Second, preliminary information needs to be shared as early as possible to enable parallel design activities. Third, there is a challenge of breaking the product down to smaller systems and subsystems in order to divide the tasks among the development team. Last, although challenging, concurrent engineering should be managed in a way that making design changes does not result in creating more design problems than the number of problems already being solved. (Yassine & Braha 2003, p. 166.)

The latter part of this theoretical background delves into the roles of sourcing and suppliers as part of the concurrent product development process. That is, from the viewpoint of concurrent engineering, the integration of R&D, sourcing and suppliers in concurrent product development is essentially what early supplier involvement comes down to.

2.1.3. Product newness, architecture, complexity and uncertainty

There may be several differences between different product development projects and therefore in this sections some key concepts to distinguish this differentiation are presented. Products and development projects differ from each other for example in terms of the type of new product, complexity, type of architecture and uncertainty. These relevant concepts are presented here.

Ulrich and Eppinger (2008) have presented the following categorization to distinguish between different types of product development projects:

1. new product platforms,
2. derivatives of existing product platforms,
3. incremental improvements to existing products, and
4. fundamentally new products.

In new product platform projects a whole new product family is developed based on a common product platform and the products of the new platform are targeted to markets that the company is already familiar with. Derivatives of existing product platforms refer to introducing new products to already existing product families. These products are targeted to known markets. Incremental improvements to existing products are about keeping the product line competitive by modifying the design and adding or reducing features to an existing product. The fundamentally new products are new both to the company and to the markets and may even target customers that the company has not served before. These type of development projects hold the highest risk but may also lead to high rewards through competitive success. (Ulrich & Eppinger 2008.)

Product development projects also differ from each other in terms of complexity. Ulrich and Eppinger (2008) compared developing a screwdriver to developing an airplane to illustrate the differences in complexity. The two projects are from totally different worlds since the airplane project requires a budget of billions of dollars and thousands of people working on the project whereas the screwdriver development project requires six people and a budget of hundreds of thousands of dollars. The more complex products can be expected to include a variety of different technologies and interfaces between systems. (Ulrich & Eppinger 2008.)

Another issue that is present in new product development project is uncertainty although the amount of it may differ in different projects. Hall and Martin (2005, p. 279) and Hall et al. (2011, p. 1149) suggested that a distinction can be made between technological, commercial and organizational uncertainty. Technological uncertainty refers to the feasibility of a technology, commercial uncertainty refers to a product being commercially worthwhile and viable and organizational uncertainty refers a company's capabilities, organizational structures and match with corporate strategies. Henderson and Clark (1990) stated that companies need to weigh whether to go with technologies

already accepted by incumbent companies or to go with more uncertain new technologies. Overall uncertainty can be seen as lack of required or wanted information to make decisions regarding for example material, manufacturing technology and supplier selections in new product development.

Products are also different in terms of their architecture. According to a definition, product architecture is *"the arrangement of functional elements, the mapping from functional elements to physical components and the specification of the interfaces among interacting physical components"*. The architecture may be modular or integral. Integral architectures typically include complex coupling between physical parts and one-to-many or many-to-one mapping. Modular architectures typically include decoupled interfaces and one-to-one mapping from functional elements to physical components. (Ulrich 1995.) Modularity therefore is an attribute which allows complex systems to be smaller subsystems while simultaneously minimizing interdependence between modules and maximizing interdependence within the modules to allow for reconfigurations by changing modules without losing the system's functionality (Campagnolo & Camuffo 2010).

2.2. Early supplier involvement in new product development

"Ask not what your suppliers can do for you; ask what you can do with your suppliers." – Takeishi (2001)

The concept of early supplier involvement requires clarification in order to dig deeper into the issue of managing it. In literature ESI has been defined in several ways and there appears not to be a single definition for it. According to one popular definition, ESI can broadly be defined as *"a form of vertical cooperation where manufacturers involve suppliers at an early stage in the product development / innovation process, generally at the level of concept and design"* (Bidault et al. 1998, p. 719). This broad definition is used in this study, albeit the focus is in product development as innovation collaboration is ruled outside of the scope. Van Echtelt et al. (2008, p. 182) define supplier involvement in more detail as they state that it *"refers to the resources (capabilities, investments, information, knowledge, ideas) that the suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part, process or service for the benefit of a buyer's current or future product development projects"*. This definition supports and complements the definition by Bidault et al. (1998) since it gives a more concrete idea of the activities that it takes to manage supplier involvement in NPD and the interaction between two companies. This study considers managing ESI in NPD as a combination of internal and external practices or managing ESI related activities within the case company and with the supplier. What constitutes 'early' appears to be a flexible concept as can be seen later in this study.

The increasing popularity and interest in ESI can be seen to be a result of companies outsourcing functions that are outside of their core competence which has made companies increasingly dependent on their suppliers and supply chains. For the past couple of decades it has been an increasingly apparent trend that companies in several industries strive to better utilize their suppliers' expertise and to boost their product development effectiveness and efficiency by involving the suppliers at an early phase of the product development process and giving them increased responsibilities regarding the designs. (Wynstra 2001.) The background of the phenomenon that is commonly known as ESI appears to be in Japanese automotive industry while today there appears to be differences in the adoption of ESI practices geographically. Birou and Fawcett (1994) pointed out that the firms in the US had advanced further than European companies in pursuing ESI practices due to intense competition.

In their study focusing on assembly-based companies outside of automotive industry, Bidault et al. (1998, pp. 729-731) found that organizational choices play a greater role in whether a company adopts ESI practices or not compared to external pressures. Therefore it is mostly up to the choices of any company to establish and increase ESI. In fact, companies in high-tech manufacturing and automotive industries appear to be planning to increase their efforts to involve the suppliers in NPD in the future (Wagner & Hoegl 2006, p. 936).

Wagner (2003) studied the intensity and scope of supplier integration of 173 companies from different industries. The study proposed that while managing supplier involvement and supplier relationships effectively is a relevant source of competitive advantage, companies still do not have systematic approaches for supplier involvement and they face challenges managing it. (Wagner 2003, pp. 12-13.) The task is not a simple one since in product development partnerships both the buying company and the supplying company have needs from each other and often these needs can be in contradiction. A balance needs to be achieved with regard to these needs to enjoy the benefits of efficient and effective collaboration which in turn may translate to competitive leverage. (Swink & Mabert 2000.)

It needs to be kept in mind that as stated by Johnsen (2009, p. 195) there is a bias in ESI literature towards rather mature high-volume industries such as the automotive industry. Therefore these theories need to be approached with care from the viewpoint of the case company which operates in high mix – low volume and most likely does not face as intense competition as in the automotive industry.

ESI does not appear to be the single accepted concept since various other studies with perhaps a bit different focus deal with similar issues. This related literature deals with concepts and themes such as supplier involvement, supplier integration, co-development between the buying company and the supplying company, product development collaboration, design outsourcing and design-or-buy decisions. While not all of these

studies have focused around early supplier involvement they appear to essentially deal with the same issues.

2.2.1. Benefits of ESI

It is essential to understand why an increasing number of companies are involving suppliers and planning to increase supplier involvement in their NPD. This raises the question of what benefits can be achieved through ESI. Several previous studies have shown that ESI may lead to significant and various benefits.

In their study Van Echtelt et al. (2008) studied the managerial activities that take place at a strategic level and at an operational level. The study recognized that managing these processes successfully can lead to both long term and short term benefits. The long term benefits include gaining access to the suppliers' technology and aligning technology roadmaps with them, achieving more effective collaboration in the future through learning and reusing the solutions from other collaborative projects. The short term benefits were suggested to be realized in part technical performance, part cost, development cost and development lead time. (Van Echtelt et al. 2008, pp. 194-197.) Distinguishing between long and short term benefits is a relevant point since ESI is not just about maximizing the short term benefits but instead the highly ambitious goal should be to achieve competitive advantage in the long term.

Wasti and Liker (1999, p. 352) studied ESI in the automotive industry focusing especially in outsourcing design to the suppliers and came to the conclusion that ESI has a positive effect to product design and design for manufacturability (DFM). These in turn could be expected to translate into higher quality. The study by Petersen et al. (2009, p. 385) supported the idea that involving suitable suppliers in new product development drives better decision making within the project which then helps in achieving better product design finally somewhat correlating with improved financial performance.

Ragatz et al. (2002) studied the benefits of ESI under technological uncertainty. Their study suggested that ESI resulted in reduced development time from concept phase to launch, increased quality, and lowered costs when utilizing target costing practice with ESI. (Ragatz et al. 2002, p. 398.) Carr and Pearson (2002) studied supplier involvement and sourcing involvement on strategic sourcing performance and concluded that supplier and sourcing involvement have a positive effect on strategic sourcing efforts in general which in turn has a positive effect on company's financial performance.

In their case study Zsidisin and Smith (2005) found that ESI can also work as means to reducing supply and design risk in addition to the more commonly mentioned benefits of time, quality, performance and cost reductions. The reduction in supply risk and design risk refers to preventing potential failures in the product or in the activities carried out by the supplier. (Zsidisin & Smith 2005, pp. 54-55.) It was found that the

risks are reduced by the means of managing outcome uncertainty, setting tasks and targets for the supplier and monitoring their performance, having shared goals in both companies and selecting the right suppliers under the right criteria (Zsidisin & Smith 2005, pp. 51-53). This risk reduction viewpoint is interesting since it implies that companies also benefit from ESI not only in terms of receiving input to the design but also in in terms of reducing risks and uncertainty related to the product and suppliers.

Trent (2007, p. 227) presented a summary of the findings of several studies with regard to benefits of supplier involvement versus cases where supplier was not involved. The benefits are presented in table 2.1. The table suggests that involving the suppliers led to significant benefits time, costs, quality and product performance.

Table 2.1 *Benefits of supplier involvement in new product development compared to projects with no supplier involvement (Trent 2007, p. 227)*

	Early	**Middle**	**Late**
Reduction in material costs	20%	15%	10%
Reduction in development cycle time	20%	20%	10%
Improvement in material quality	20%	15%	15%
Reduction in development costs	20%	10%	10%
Reduction in manufacturing costs	10%	12%	10%
Improvement in product functionality, features and technology	20%	10%	10%

However, some studies have come to a contradictory conclusion stating that no significant benefits were associated with applying ESI practices. The studies by Hartley et al. (1997) and McCutcheon et al. (1997) pointed out that involving the suppliers early and giving them more responsibility of the design did not result in time and cost reductions and quality improvements. Additionally, for example Primo and Amundson (2002, pp. 49-50) studied the benefits and found that ESI was especially positively correlated with different aspects of product quality while it was not seen to offer improvements in terms of time and cost reductions. It is not, however surprising that also these type of results have been found since organizational contexts, cultures and people are different. It can also be stated that different companies may seek to achieve different benefits through ESI. These opposite results may indicate that it is not an easy task to manage ESI and on the other hand if it was easy, every company would have been doing it successfully and intensively already for a long time. It could be assumed

that the key in whether benefits or nothing is achieved is dependent on how to manage ESI and therefore it makes sense to study the success factors and barriers presented in literature.

2.2.2. Barriers, enablers and success factors to ESI

Although it is a difficult task to define what exactly it is that makes ESI work in each case as companies and their contexts are different, a company should understand the general factors that drive success in ESI as well as the typical barriers and risks related. Many studies have pointed out success factors that have been present in cases where the benefits of ESI have been successfully tapped into. Similarly, typical barriers and risks related to ESI have been presented in literature. In order to access and tap into the benefits presented in the previous section a company should strive towards establishing the recognized success factors in their practices while mitigating and overcoming the barriers.

Wynstra et al. (2001) presented three critical issues to take into account and to overcome in order to manage ESI successfully. They divided the critical issues into three categories based on their source of origin: the buying company, the supplying company and the relationship between the buying and the supplying company. Poor communication and lack of trust can be attributed to the relationship between the supplier and the buying company. This may result in the companies having unequal expectations about the collaboration, making false assumptions about the goal and responsibilities which implies the need for clear a clear project plan, communicating the expectations and activities that the supplier should carry out. Mistrust between the companies will slow down the collaboration when both parties spend time in avoiding risks. Additionally, technical mismatch may result in communication challenges in practice if the companies for example do not have matching CAD systems. Additionally, several critical issues can be attributed mainly to the suppliers. The suppliers might not have the required capability to participate in R&D collaboration and the buying companies might end up selecting the wrong suppliers if their selection criteria does not take capability into account. Additionally, the suppliers might not have the ability or willingness to commit their resources if the buying company only represents a small portion of their total revenues and if there is strict competition about the supplier’s resources among the customers. Then there are the issues related to the buying company. If the company lacks a defined product development process and strategy it will be more challenging to communicate the process and manage the collaboration. Resistance may occur in internal departments since R&D personnel may feel that bringing the supplier in on the project makes work more difficult or that their work is threatened. Additionally the sourcing personnel may feel that they do not have enough information to make decisions regarding supplier selections with unfinished designs. If the attitude towards involving the suppliers is negative and there is no trust

in their capabilities, the employees may even resist the collaboration by making it even more difficult. (Wynstra et al. 2001, pp. 159-160.)

In their case study in the electronics industry, McIvor et al. (2006) presented barriers for adopting ESI practices. These barriers are in line with the ones presented by Wynstra et al. (2001). The barriers are presented in table 2.2.

Table 2.2. *Barriers to adopting ESI practices (McIvor et al. 2006, p. 391)*

- Playing suppliers off against one another in the design process in order to extract more favorable terms
- Lack of clarity and inconsistencies in the policy guidelines for the level of supplier involvement and the time of supplier selection in design
- Influences from corporate level can be detrimental to the management of ESI at local level
- Design personnel resistant to increasing the level of involvement of suppliers in the design process
- Conflict between members of the integrated product development team
- Perceptions of the re-design cost reduction process as being that of switching suppliers
- Suppliers are suspicious of the motives when requesting cost information
- Suppliers not confident enough of the accuracy of their costing structures to share them with their customers
- Incompatibility of systems of the company and its key suppliers
- Not enough dedicated resources to jointly work with key suppliers
- Annual contract negotiations perceived by suppliers as a barrier to effective cost improvement programs for the life of the contract
- The exercise of power by the customer in the relationship can be detrimental to effective ESI
- Culture of people in both the company and suppliers is a considerable barrier to the principles of ESI such as supply base reduction, cost information sharing and resource commitment from top management

Four main themes that are behind the several barriers found at their case company were found: top management influences, supply management approach, culture and technology implications. It was stated that top management support is needed in both companies and at different levels to enable internal and external collaboration that aims towards involving the supplier early. The supply management approach would have to be such that there are clear strategies for outsourcing decisions and that the collaboration is based on mutual benefits instead of opportunistic abuse of power, switching suppliers during the project and renegotiating contracts annually.

Additionally, companies building collaborative ESI partnerships should have matching cultures with regard to doing teamwork and building trust. In terms of technology implications a distinction between predictable and unpredictable development projects was suggested since in the case of unpredictable projects, unlike with predictable ones such as in the automotive industry, there is more uncertainty about the supplier selections. It was stated that in more predictable projects the suppliers are more likely to have better understanding about their responsibilities and roles in the project as they might be specialized in a certain type of module. (McIvor et al. 2006, pp. 391-395.) The last notion is rather interesting in terms of this study as it calls for a contingency approach to take into account the features of a certain project since projects are different across different industries. The study by Ragatz et al. (1997) concluded that the key barriers to overcome in achieving success in ESI are fear of sharing proprietary information with the supplier in the fear of them leaking them to competitors on purpose or by accident and the so called not-invented here syndrome (Ragatz et al. 1997, pp. 199-200).

Dowlatshahi (1998) proposed prerequisites and recommendations when implementing ESI. They found that when implementing ESI there has to be a formal and planned out way of doing it as well as an entity who is mainly responsible for the initiative. Additionally they stated that commitment to ESI programs requires the suppliers to be willing to commit to a long-term relationship and therefore the involved supplier should be in a partnership type of relationship with the buying company. Moreover, ESI requires cross-functional teams and effective co-operation within the team in order to facilitate communication between the relevant stakeholders. The last prerequisite presented for implementing ESI was top management support. Additionally they recommended that the activities carried out by various stakeholders should be carried out simultaneously even though that they are independent and therefore the culture of the company was seen to be in a key role. The culture should support cross-functional collaboration in product development. (Dowlatshahi 1999, pp. 161-163.)

Several factors were recognized as must-have prerequisites for which closer collaboration and success can be built upon. These items are presented in figure 2.4.

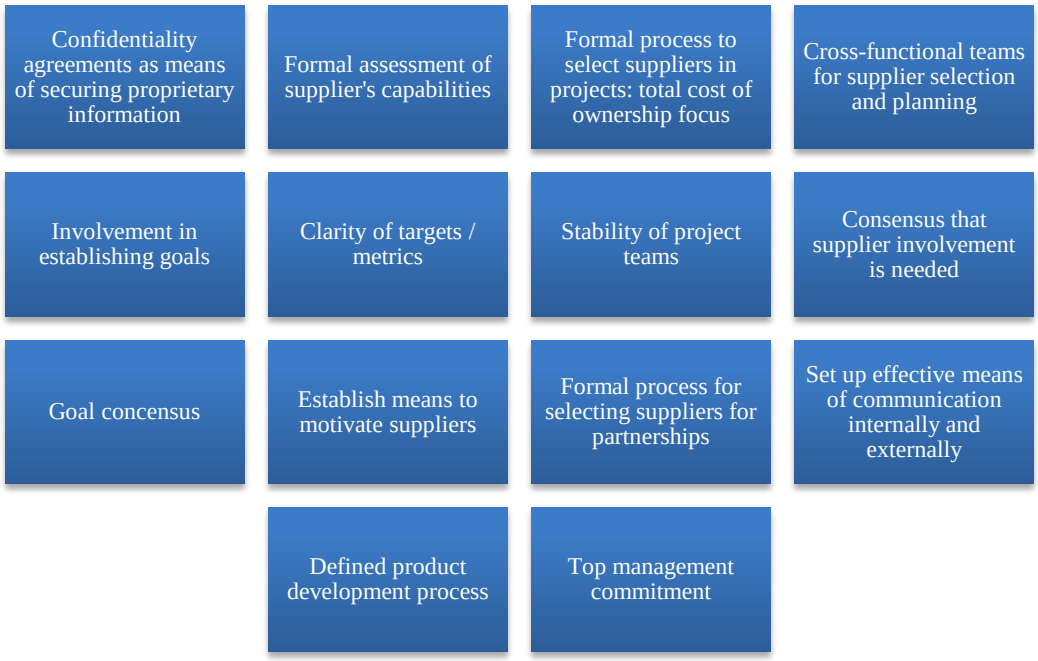


Figure 2.4 *Pre-requisites for early supplier involvement (Adapted from Ragatz et al. 1997, pp. 199-200; Jiao et al. 2008, p. 930; Dowlatshahi 1999, pp. 161-163)*

Being aware of the barriers presented above and the prerequisites provide a good starting point for making it possible to establish ESI practices. However, in literature success factors that made the biggest difference between the most successful and least successful companies in ESI practice have also been recognized. Ragatz et al. (1997) studied the success factors of ESI in NPD by conducting a survey targeting 60 companies. They conceptualized two themes for overcoming the barriers related to ESI based on the major differences in the most successful and least successful cases of ESI: the relationship structuring differentiators and asset allocation differentiators. The relationship structuring differentiators aim at deepening the collaboration between the buying company and the supplying company and these activities would include top management commitment from both companies, shared training, mutual trust and confidence in each other's capabilities, commonly agreed performance measures and risk and reward sharing. These differentiators can be seen as enablers for sharing actual assets such as intellectual assets, human assets and physical assets between the companies (Ragatz et al. 1997, pp. 199-200.) In practice this would mean for example sharing information regarding technologies and requirements, co-locating personnel and establishing matching information systems.

In his comprehensive literature review on ESI, Johnsen (2009) presented a summary of the success factors of supplier involvement divided into three categories. This summarizes the topics discussed in this section rather well. The success factors and related categories are presented in figure 2.5.

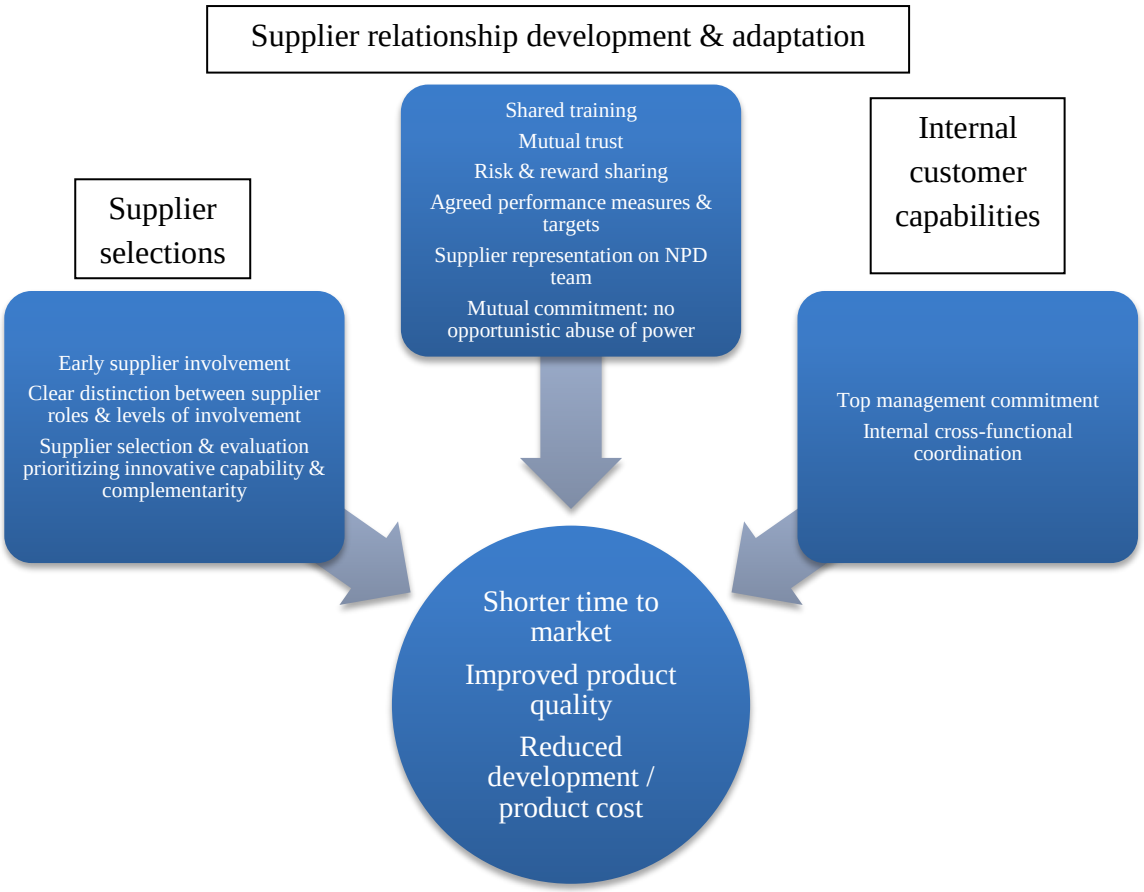


Figure 2.5 *Summary of success factors for ESI in NPD (Adapted from Johnsen 2009, p. 195)*

As this thesis deals with the practices of managing the involvement during a product development process, the key question as compared to the success factors is how to manage the internal cross-functional coordination, how the actual involvement and supplier selection is managed and how to collaborate in practice. The various success factors and barriers presented here provide a general understanding of what to strive for and what challenges are likely to occur. However, a more detailed view about the factors that influence managing ESI is required in order to determine the most fitting practical approach for the case company.

2.2.3. Managing internal collaboration for ESI

The success factors and barriers presented in the previous section suggested that a company's internal capabilities and collaboration are in a key role in ESI success. This section digs deeper into how internal collaboration should be arranged to best facilitate ESI. The essence of concurrent engineering implies that good communication among the project members is required in order to manage the development efforts of several members of the project team. It also implies that since sourcing is typically the interface between a company and its suppliers the importance of sourcing involvement in new product development is in key role.

The study by Koufteros et al. (2005) suggests that with ESI internal integration enables external integration and therefore companies should first align their internal collaboration in a way that cross-functional collaboration is possible. Internal integration on the project level refers to establishing concurrent engineering practices with representation from members of different organizational functions. External integration refers to involving the suppliers as a part of the concurrent engineering process. (Koufteros et al. 2005, pp. 121-125.) The study by Das et al. (2006) proposed that for every context there is an optimal practice for supplier integration which is a combination of certain internal and external practices. The optimal set of practices, however, varies between different industries and is affected by product life-cycles and production strategies, competitive environment of supply network, organization size and sales and internal managerial practices (Das et al. pp. 577-578). Therefore the integration activities pursued should be chosen specifically in each context with organization specific factors in mind as the practices are not likely to be replicable in other settings.

Wynstra et al. (1999) studied the involvement of sourcing in product development not only during product development projects but in different management arenas in order to recognize how such sourcing involvement in R&D activities could lead to both short term and long term benefits. They concluded that sourcing and product development should be integrated on several levels to best facilitate ESI. (Wynstra et al. 1999, pp. 134-139.) Wynstra et al. (2000) studied the driving factors that increase the need for sourcing involvement and enabling factors that support sourcing integration with R&D. Their study suggested that the need for sourcing involvement is increased by company size, importance of product development, overall degree of dependence of suppliers and complexity of production. The involvement of sourcing is enabled by a fitting organization of sourcing department and product development team, exchanging and recording information and the quality of human resources. (Wynstra et al. 2000, pp. 135-141.)

Wynstra et al. (2001, p. 161) later introduced these arenas in a framework that presents integrated product development and sourcing (IPDS) processes and tasks. The latest update of the IPDS model was presented by Van Echtelt et al. (2008, p. 196) who revised the framework by Wynstra et al. (2001) making it more general. This model separates the management processes into two levels: short term operational management and long term strategic management which are in constant interaction between each other. The framework by Van Echtelt et al. (2008) rather well summarizes the activities that need to be taken into account in managing ESI on a general level. The model does not provide suggestions as to who should manage the activities but instead emphasizes the importance that the activities are managed. All of the activities have either informing, coordinating, timing, prioritizing or mobilizing purpose (Wynstra et al. 2003, pp. 77-81). On the strategic level companies need to align their operations in a way that it supports managing ESI on the operational level. This would include making decisions

about what technologies to keep in-house in terms of design work, establishing and evaluating supplier performance, developing desired capabilities for the suppliers, setting guidelines for collaboration and pre-selecting suppliers for involvement in future projects. (Van Echtelt et al. 2008.) The IPDS framework and related activities are presented in figure 2.6.

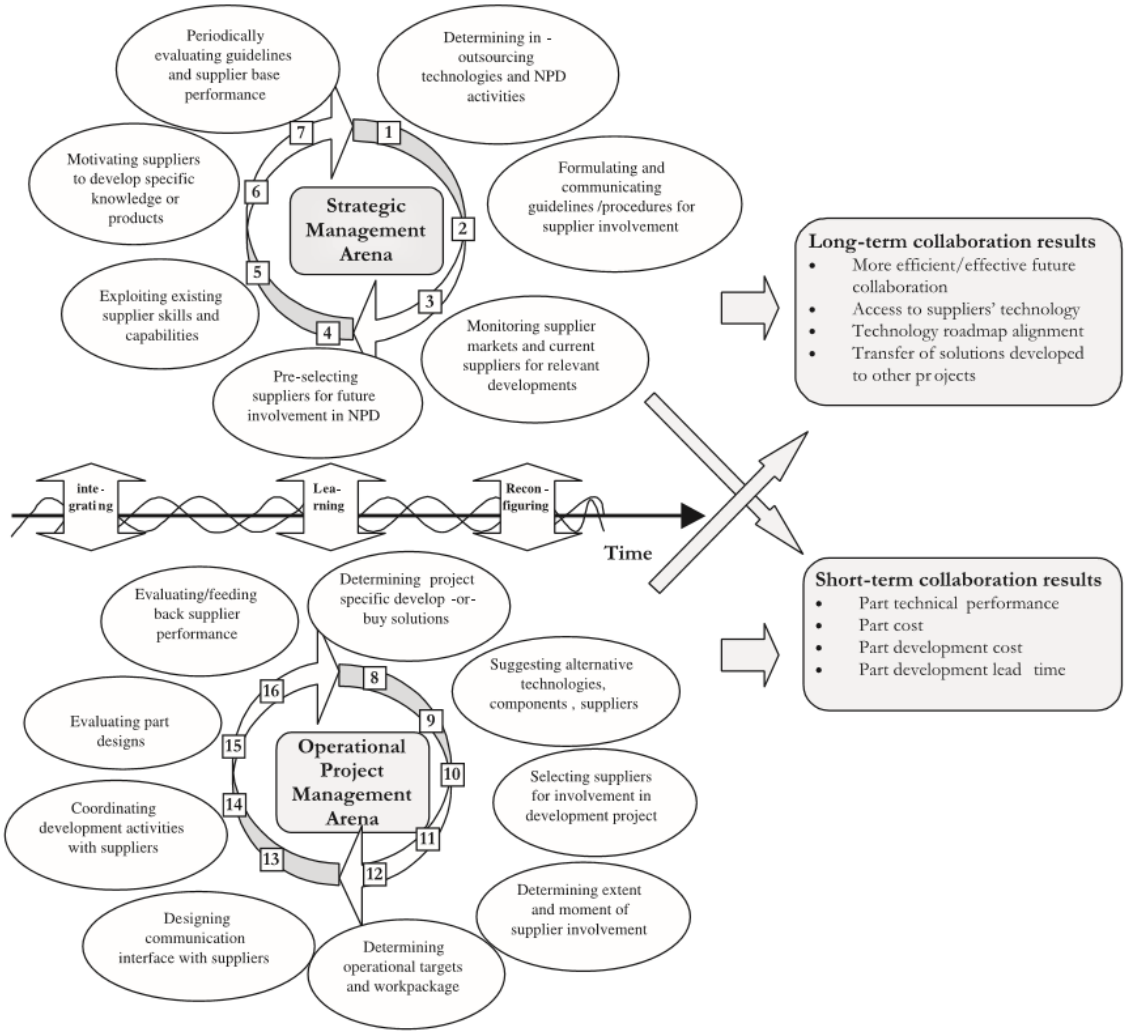


Figure 2.6. *The integrated product development and sourcing framework (Van Echtelt et al. 2008, p. 196)*

On the operational level decisions are made regarding project or part specific design-or-buy-design: whether design work will be outsourced to suppliers. This is followed by determining alternative solutions regarding components, technologies and suppliers. Suppliers are then selected for involvement based on pre-selections made on the strategic arena. Based on these consideration the apt extent and moment of involvement are determined. Operational targets and work package are then set to make it clear what the goal is and what the supplier's role and responsibilities are. The companies then plan the communication interfaces for the project and coordinate development activities with evaluation and feedback loops regarding designs and performance. (Van Echtelt et

al. 2008.) The model is quite generic but provides a good outline of the activities and considerations.

Van der Valk and Wynstra (2005) tested an early version of the framework by Van Echtelt et al. (2008) in food industry and concluded that the presence or absence of the activities described in the framework provide a good outline on predicting and explaining the successfulness of ESI. Additionally, they suggested that the IPDS framework is generic enough to be tailored for the needs of a company in food industry. (Van der Valk & Wynstra 2005, p. 691.) Therefore this framework could also prove to offer fitting ideas for the case company as well and in this study it is used as a general reference point. Compared to the IPDS model the aim of this research is to mainly discover the most suitable way for the case company to manage the operational arena and provide more information regarding the things that should be taken into account at each step. This framework implies that the events taking place on the strategic arena also affect the decisions and activities on the operational arena. However, the aim of this study is not provide the practices for strategic management of ESI although the connection to the operational arena is tight.

Wynstra et al. (2001, pp. 160-165) suggested that companies pursuing involving suppliers early should first address the internal critical issues by paying attention and managing three matters: identifying their IPDS processes and tasks in different arenas, developing a suitable organization to run the identified tasks and finally staffing that organization with people who possess a right set of skills to collaborate and fulfil the tasks. They suggested four popular organizational configurations that support carrying out the tasks. The first configuration is having separated teams or organizations for managing operational purchasing and supplier relationship management. The second configuration is setting technology experts to work in the interface of sourcing and R&D to support both functions and exchange information between the two. The third organizational configuration is sourcing representative participation in cross-functional product development teams. The fourth and final configuration is one that ties sourcing and R&D together into an integrated function by establishing so called commodity teams where sourcing and development representatives work together in selecting suppliers and approving parts to design or buy. The people in these organizations should have the right social skills and attitudes as well as technological and commercial knowledge. (Wynstra et al. 2001, pp. 160-165.) Sourcing participants in product development project should develop deep knowledge about the products and product families as well as technologies and related trends. In order to collaborate with the technological experts in cross-functional environments good communication and leadership skills are important. (Handfield et al. 1999, pp. 80-81.)

What then is the input that sourcing brings to a new product development project? Schiele (2010) studied the dual role of sourcing in NPD in six best practice companies. The study suggested that sourcing has an essential role in supporting the R&D process

while managing the costs and the responsibilities given to the supplier. This points at the importance of having a sourcing representative or representatives as participants in the product development team since sourcing facilitates the collaboration between the supplier and the development team and therefore eases managing supplier involvement. The study eventually suggests that companies should utilize technology roadmaps and link them to sourcing strategies to ensure long term alignment of company's technological demand and matching supply from the suppliers. Also this study recognizes that companies should establish fitting sourcing organizations to best enable the dual role of sourcing in supporting R&D. (Schiele 2010, pp. 149-150.)

The role of sourcing, however, appears to be different in cases of high technological uncertainty in comparison to cases of low technological uncertainty. According to case studies by Melander and Lakemond (2014) under high technological uncertainty sourcing has a limited role in selection of technology, supplier selections are often made unsystematically and sourcing is not consistently involved throughout the project. Supplier involvement and collaboration is managed differently in cases of high technological uncertainty and in cases of low technological uncertainty the input from the suppliers is typically related to manufacturability related issues and accordingly sourcing assumes different roles in these cases. In general and regardless of the amount of technological uncertainty, sourcing was stated to have an important role as an entity that facilitates collaboration between R&D and suppliers, in supplier selections and as a problem solver regarding conflicts of interest, strategy and costs. (Melander & Lakemond 2014, p. 115.)

O'Neal (1993) studied concurrent engineering and as a part of it the involvement of sourcing and suppliers in new product development as a method for answering to the challenges of global competition by improving on quality, time and cost. These can be achieved by the key features of concurrent engineering which are customer focus and cycle time reduction which in practice means developing the products and features that are right for the customer and doing it right the first time. O'Neal argues that ESI and early sourcing involvement can actually be seen as a requirement for the concurrent engineering process to work since they may be responsible for manufacturing major parts of a product therefore contributing to the cost, quality and time. Additionally, sourcing involvement continues throughout project after evaluating and selecting potential candidates as they assume responsibility for ensuring that quality, cost and logistical requirements are met. (O'Neal 1993, p. 8.) Concurrent engineering and ESI appear to have a natural connection since concurrent engineering also requires the concurrent activities from suppliers to work optimally and on the other hand ESI has the same agenda as concurrent engineering. In their case study, Rouibah and Caskey (2005) studied managing concurrent engineering with ESI and discovered challenges in managing it in the early phases of product development due to high levels of iteration and product complexity. (Rouibah & Caskey 2005, p. 519.)

In their best practice report of a case company, Smith and Zsidisin (2002) present an ESI process implemented in a company operating in aerospace industry. The process begins with evaluating the projects that might benefit from ESI based on the requirements. In the context of that case company the importance of aggressive but realistic target costing practice was seen as an essential part of the ESI process. Their process also included engaging internal stakeholders in order to determine technology alternatives and final commodity breakdown. (Smith & Zsidisin 2002.) The utilization of target costing can work as a method of setting a common target for the cost of a part or system and challenging the suppliers to achieve that target cost by joint value engineering activities. Afonso et al (2008) studied the influence of target costing on NPD success and came to the conclusion that target costing drives NPD success. The roots of target costing are in Japanese automotive industry (Kato 1993) and the process of target costing consists of three steps (Cooper & Yoshikawa 1994). The first step is to identify the target price of the product followed by determining the target margin (Cooper & Slagmulder 1997, according to Afonso et al. 2008, p. 559). Thirdly value engineering and functional cost analysis are applied to meet the target cost by reducing unnecessary features while preserving the required ones (Yoshikawa et al. 1994). However, it should be kept in mind that in this case company the main driver for adopting ESI practice was cutting costs.

It can be concluded that managing ESI should be a joint effort between sourcing and product development on different organizational levels. On the operational level the key activities include selecting suppliers, determining the extent and moment of supplier involvement and coordinating the collaboration with the selected supplier. The next sections will dig deeper into these key activities and the factors that influence the decisions made.

2.2.4. Supplier evaluation and selection for early involvement

It needs to be understood which suppliers should be involved in NPD and what are the determinants to evaluate and take into account in order to make the decisions about supplier selections. A relatively small number of suppliers should be chosen for early product development collaboration (Trent 2007, p. 226). What are the determinants that make a good ESI supplier? Considerations need to be taken in both strategic and operational levels since on strategic level decisions are made regarding which suppliers should be given new business in general and in projects considerations need to be made about which suppliers to select for involvement in that specific project.

There are basic considerations that should be taken into account when scouting for a suitable ESI companion. The supplier should be trustworthy so that the buying company can be certain that proprietary information will not leak through that supplier. Moreover, the supplier should possess the necessary capabilities to support the buying company’s design efforts and be willing to provide the resources for collaboration. It

should be taken into account whether the supplier has previous experience of such early design collaboration and if the company provides such services to other companies or even to competitors. It is beneficial if the supplier uses compatible design software with the buying company. Additionally, the amount of investment that the supplier allocates to R&D activities may give indications about the supplier's fit. Alignment of technological roadmaps indicates that the companies could collaborate in the long term in technological sense. (Trent 2007, p. 227.)

Relationship specific factors play an important role in supplier involvement in NPD. Walter (2003) studied these relationship specific factors' influence on managing ESI. Trust and commitment of the supplier were found to be critical drivers for ESI and therefore companies should shift from transactional arm's length relationships towards considering their key suppliers as partners. The study also suggested that supplier relationship managers in buying companies should recognize and assume their role as promoters of ESI and key contributors in driving the suppliers to develop the required capabilities. Greater levels of supplier involvement were found to be connected to higher amounts of so called supplier-specific adaptations that tie companies together. These adaptations refer to the investments regarding knowledge, structures and processes by the buying company to better facilitate collaboration with a supplier. (Walter 2003, pp. 728-729.) These adaptations could mean for example making changes to the R&D process or to a part design at the buying company based on the supplier's feedback or jointly investing to a new machine. Therefore these adaptations could take place on the strategic arena or in the project management arena. However, not all supplying companies should be elevated to partnership status and involved early. In order to develop long-term relationships with suppliers, buying companies typically need to rationalize their supply base and reduce the number of suppliers in a way that more business is concentrated towards the most capable and high performing suppliers. (Sarkar & Mohapatra 2006, pp. 157-158). This can be seen as a way of increasing mutual commitment and interdependence.

Trust should be built with the suppliers that the buying company wants to further involve in their NPD in the future as this leads to higher perceived satisfaction and performance in collaboration. Additionally, supplier's flexibility in the collaboration as well as shared planning activities have on effect on the perceived performance of the collaboration. (Johnston et al. 2004, pp. 36-37.) The two companies should therefore develop an understanding and trust towards each other. Möller and Törrönen (2003) suggested that suppliers' value creation potential is the factor to be assessed when considering long-term partnerships and this potential can be evaluated based on their capability (Möller & Törrönen 2003, pp. 115-116).

According to Petersen et al. (2005, p. 385) the supplier's culture and cultural fit with the buying company has a significant impact on the effectiveness of collaborating with the supplier regardless of the product development phase and the level of responsibility

given to the suppliers. The culture should therefore be compatible with the buying company's culture regardless of the timing or extent of involvement.

In line with reducing the supplier base, developing partnerships and building trust, Schiele (2012) suggested that buying companies should strive to become a preferred customer for their preferred suppliers in order to facilitate product development collaboration that enables competitive advantage. The study also stated that literature does not present evidence of cases where being the supplier's preferred customer would lead to higher prices which could be considered a risk as the buying company would become increasingly dependent on the supplier. On the contrary, it has been found that being the preferred customer to a supplier leads to fair and open pricing behavior. Selecting suppliers as strategic partners and aiming towards becoming their preferred customer requires strategic considerations. The suppliers should be assessed based on their technological fit in the long term and importance of the technology provided by the supplier should be assessed. Additionally, the proportion of the buying company's spend in relation to the supplier's total revenues should be considered since existing business raises the importance of the customer in business sense. Cultural match and past experience of being treated as a preferred customer are indicators of the supplier being a good fit for long term collaboration. In terms of personnel, the supplier should have designated key account managers for the buying company. (Schiele 2012, pp. 47-49.) Being each other's preferred partners appears to be a state to strive for to best facilitate product development collaboration and ESI.

To determine strategic suppliers it might be beneficial to assess the importance and risks related to the technologies supplied. Kraljic's matrix which is also known as the purchasing portfolio is a way for assessing this. The matrix categorizes supplied technologies in four categories in terms of supply risk and importance of the technology in terms of value add. These categories are strategic items and critical items which are characterized by high value add, and bottleneck items and non-critical items which are of lower value add. (Kraljic 1983, pp. 111-112.) Parker et al. (2008, p. 71) found that sourcing of strategic items calls for a closer involvement. The position of the supplier and supplied technology in the matrix should be considered. However it needs to be kept in mind that the portfolio may not always remain stable as buying companies may need to alter their portfolio and apply new strategies to reposition items within the matrix due to changes in the supply market, supplier situation and internal overall strategies (Gelderman & Van Weele 2003).

The starting point for ESI practice in companies can be quite different and therefore the companies might not have such a good idea about the capabilities of their existing suppliers and new suppliers. Information is therefore in key role in selecting suppliers. Petersen et al. (2003) presented a model for successfully integrating suppliers into NPD based on case studies with 17 companies. Their study suggested that before involving suppliers to new product development the suppliers should carefully be evaluated and

selected and that the involved suppliers should be trusted and have a good history of such collaboration. The more knowledge the buying company has about the supplier the more likely it is that greater amount of information is shared during NPD and supplier is involved more closely. Especially sharing technology information was seen to result in more supplier involvement and better outcomes of collaboration. In cases of high technology uncertainty it is more likely that buying and supplying companies exchange information in NPD teams and in these cases it is especially beneficial to share technology and have the supplier representative as a member of the project team. (Petersen et al. 2003, pp. 295-296.)

Melander (2014) discussed strategies for gathering information of the suppliers and information sources regarding the relational, technological and design capabilities of suppliers. The supplier capabilities can be evaluated based on previous experience of collaborating with the supplier and gathering information on the supplier's current situation in order to manage technological uncertainty by selecting fitting suppliers. Information based on previous collaborations can be obtained from supplier participation in previous NPD projects, from strategic meetings and by assessing the supplier's supply to the company's existing products. Information about the current state of the supplier's capabilities can be sought by visiting the suppliers, studying technology reports and investigating the supplier's market reputation. Suppliers' technological capabilities were found to be important regardless of the level of technological uncertainty in the projects whereas the importance of relational capabilities of the supplier were highlighted under high technological uncertainty. (Melander 2014, pp. 122-124.) In cases where the supplier is not known, more effort is needed to gathering information from them.

Schiele (2006) studied how to detect innovative suppliers and proposed several characteristics of the supplying firm and of the buyer-supplier relationship as well as enabling and supporting factors that are related to achieving innovative results with the supplier. These characteristic and enabling factors would suggest that the company is more likely to be a partner that can undertake more extensive involvement in the buying company's new product development. Character of the suppliers should be considered since specialized companies are typically more innovative than generic contractors. Short geographical proximity is an enabling factors since companies are more likely to be successful in joint development if their distance from each other is short. Development capabilities and development projects with other customers are indicators of innovative capabilities. The relationship should be based on trust and commitment and the supplying and buying company should have improvement programs together. (Schiele 2006, pp. 928-932.) Also Petroni and Panciroli (2002) based on their study from food machinery industry suggested that innovativeness can be considered as a criteria considering suppliers for involvement and that suppliers can be grouped based on their innovative capabilities. Suppliers may then be given different roles in the customer's NPD based on their capability.

It would seem natural to evaluate the activities that a supplier carries out in product development collaboration at different phases of the process. Le Dain et al. (2011) presented a framework for evaluating a supplier's co-design performance during NPD. The framework makes a separation between different supplier activities at different phases of product development as to indicate that different measurable activities and different capabilities are required from suppliers at different phases of the process. The areas to measure are relational skills, project management skills and knowhow on the delegated product and delegated process. Moreover, these things to measure may be related to proactiveness, effectiveness, efficiency. (Le Dain et al. 2011.) This raises the question of what are the actual activities are expected of the supplier at different phases of product development and in different extents of involvement. This type of evaluation approach could be utilized to evaluate the supplier's capability during a project and the information could be used to support future involvement decisions and supplier development roadmaps. The approach also takes into account for example cost related capabilities of the supplier: it is deemed important that a supplier is able to share cost information openly during the development process.

In addition to evaluating and selecting suppliers for strategic partnerships which better facilitates ESI, companies still need to make supplier selections on the operational level in each product development project. The IPDS framework suggests that suppliers could be pre-selected to projects (Van Echtelt et al. 2008). Reducing the supplier base would mean that the supplier selections were limited to a short list of potential suppliers. The actual considerations when selecting a supplier for involvement in a certain project are not well covered in the IPDS framework and especially when technological uncertainty is present and if there are several technology and supplier options it might not be such a straightforward task to simply select a supplier.

Handfield et al. (1999) studied ESI practices and suggested models and things to consider in managing ESI based on case studies in 17 manufacturing companies and surveys conducted in 134 companies. They proposed a generic model for reaching consensus on selecting a supplier for involvement in NPD projects and proposing suggestions about the suitable moment of involvement. The model includes first recognizing the potential supplier candidates and evaluating whether they are acceptable based on history or other pre-qualification. The qualification is based on evaluations about the supplier's cost level, technical competence, quality, capacity and ability to meet the schedule requirements. The process next includes assessing the risk regarding the fit of technology roadmaps and the degree of technological change and evaluating the supplier's design expertise (Handfield et al. 1999, pp. 64-65.) The model is presented in figure 2.7.

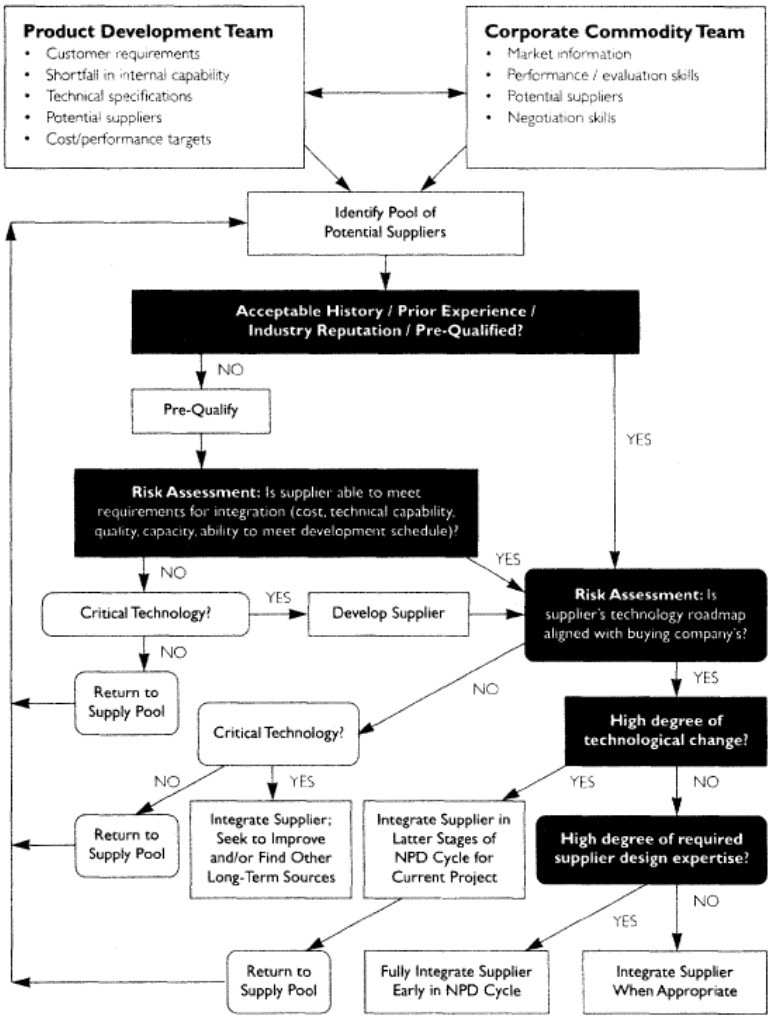


Figure 2.7. *Process model for reaching consensus on supplier to integrate into NPD (Handfield et al. 1999, p. 65)*

Even though that the soft factors such as trust, culture and innovative and design capabilities are important when selecting supplier to ESI collaboration it still needs to be kept in mind that in business there are also cost and schedule pressures. Handfield et al. (1999, pp. 80-81) claim that knowledge about the suppliers' capabilities with regard to matching the buying company's cost, quality and schedule targets is in key role in successful ESI practice. Moreover, the buying company should have access and visibility to the suppliers' technology roadmaps to evaluate whether it matches with the company's internal technological roadmap with regard to future product development. This can be seen as a risk assessment to ensure that the technology will be available in the future as well. The role of sourcing business unit was seen to be essential in selecting and developing suppliers whose technologies match the company's current and future needs which increases the need for supplier development and negotiation skills to make the right choices and drive change to the suppliers. This was seen to necessitate close co-operation between R&D and sourcing as well as new methods of evaluating the supplier in terms of technological and development orientation in

addition to more traditional measures such as price, quality, delivery times and service. (Handfield et al. 1999, pp. 80-81.)

Trent (2007, p. 232) suggested that the same supplier who is involved early and who provides input to the design should be the one who also does the volume production. Therefore the suppliers involved should be ones that are considered potential volume suppliers. This emphasizes the importance of being aware the supplier's capabilities also with regard to costs and other factors at an early phase.

The study by Melander and Tell (2014) suggested that the amount and nature of uncertainty related to a new product development project has an effect on technology and supplier selections and that different selections can be explained through the effects of uncertainty. Due to technological uncertainty it may be challenging to determine which technology will be the preferred technology in the future since it may become obsolete. Additionally, technological uncertainty is caused by the complexity of the system as determined on the basis of the number of elements and interdependencies in the parts and whether the product architectures are integral or modular architectures. (Melander & Tell 2014, pp. 114-116.) Under high levels of technological, commercial and organizational uncertainty companies attempt to remain flexible during product development instead of committing itself to one certain supplier. (Melander & Tell 2014, pp. 114-118.) It could be argued that in cases of long product life-cycles uncertainty about whether a technology is available and preferred in the future is key to take into account.

Some companies appear to utilize supplier competitions to seek for the best candidate for co-development collaboration in new product development projects. The idea in these competitions is to already engage and challenge the suppliers at an early phase to develop and present their solution and cost information for a certain part or system of a product. (Zsidisin & Smith 2005, Langner & Seidel 2009.) However, it appears that this type of approach might be feasible in contexts where suppliers are highly specialized in designing and delivering certain types of modules that are part of the end product such and the buying companies have a lot of power over the suppliers such as in the automotive industry. This does still imply that suppliers could be involved in selection process by seeking preliminary information from them and giving them a chance to win the business.

In projects the involved suppliers should possess the required capabilities but it needs to assessed what exactly it is that is expected of them and when would their input be needed. Much was discussed about the importance of supplier capabilities but these capabilities need to be in line with the role they are assigned with and on the other only roles that fit the suppliers capability should be assigned to them.

2.2.5. Extent and moment of involvement and influencing factors

As proposed in the collection of ESI success factors and the IPDS framework there should be a distinction between the extent to which the supplier is involved as well as the timing of involvement. It is key to understand the factors that should be considered when determining what type of role that should be assigned to a supplier and when they should be involved. In this section different extents and moments of involvement and influencing factors are discussed.

Petersen et al. (2005, pp. 378-379) presented a framework for distinguishing between different levels of supplier responsibility when involved in the buying company's product development. The responsibilities on this spectrum of supplier involvement are divided into four classes: no supplier involvement, White Box, Gray Box and Black Box. With no supplier involvement, the supplier is only provided with the fully finished designs and expected to manufacture accordingly. The supplier therefore has no influence on the design. In White Box collaboration the buying company seeks consultation on the design from the supplier whereas in Gray Box level of involvement there are joint development efforts with the supplier. In Black Box level of involvement the supplier assumes the primary responsibility of the design indicating meaning that the design work of a part or system is fully outsourced to a supplier. (Petersen et al. 2009, pp. 378-379.) The framework is presented in table 2.3. The supplier's responsibility increases when moving right on the framework.

Table 2.3 *Spectrum of supplier involvement (Adapted from Petersen et al. 2005, p. 378)*

None	**White Box**	**Gray Box**	**Black Box**
No supplier involvement. Supplier produces according to buyer-provided specifications or prints.	Buyer informally consults with supplier about design issues. Supplier is not part of the design team.	Supplier assumes greater design responsibility. Joint development effort between buyer and supplier. Supplier may be part of the design team.	Design is primarily supplier driven based on buyer's functional specifications or requirements. Supplier is often a formal design team member.

This classification provides a good idea of different supplier roles although it can be assumed that different types of coordination and different shades of colors could be

needed and found from within these boxes. In fact, Le Dain et al. (2010, p. 84) made further distinctions between supplier responsibilities and for example divided the gray box type of involvement into two based on whether the buying company or the supplier has the intellectual property rights (IPRs). However, the key question is what type of involvement from the supplier would be most suitable in the big scale (the most typical case), what sorts of involvement might be needed in projects in different case and what are the determinants to consider.

The first considerations regarding the levels of involvement should be made on the strategic level since these decisions deal with whether to insource or outsource design efforts. Handfield et al. (1999, pp. 66-67) suggested that as a part of ESI considerations a company should systematically evaluate which design efforts to outsource and which to keep in-house similarly to making make-or-buy decision regarding manufacturing. Additionally, companies should proactively look into the future and develop technologies which can then later be utilized in future products (Handfield et al. 1999, pp. 74-75). However, these decisions may also be present in different organizational and product architectural levels with several factors to consider in decision making as presented in figure 2.8.

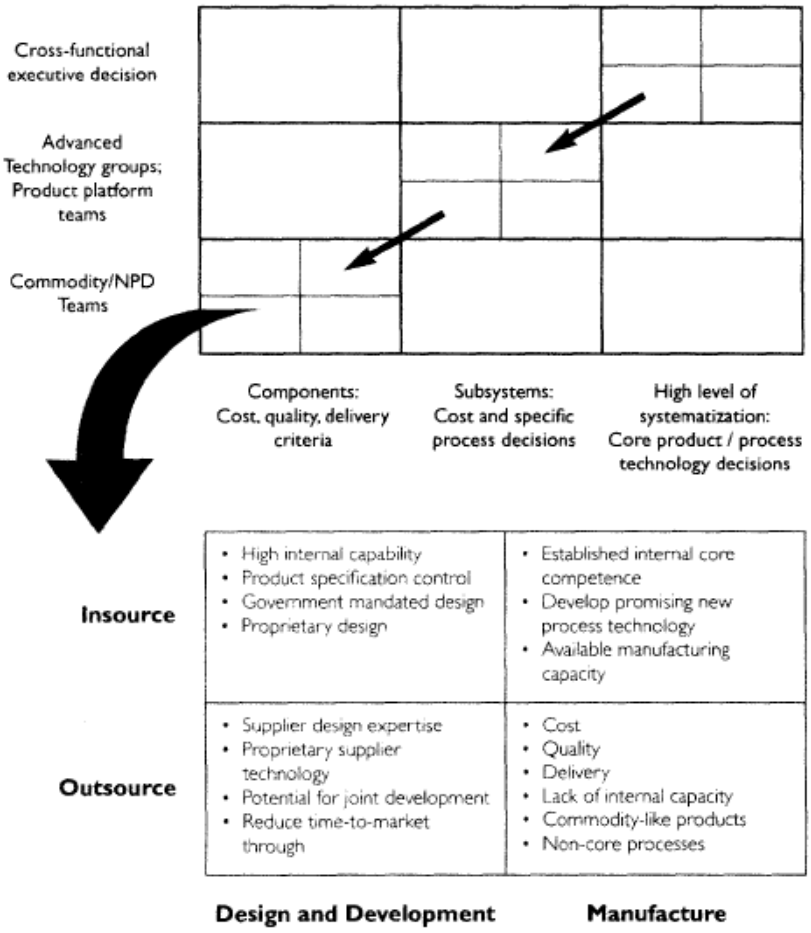


Figure 2.8. *Insourcing and outsourcing decisions (Handfield et al. 1999, p. 67)*

In accordance with different extents of supplier involvement and different phases of product development process there are different possible moments to involve a supplier. It appears that the extent and moment of involvement are closely related topics. As presented by Handfield et al. (1999, p. 62) it is possible to involve suppliers at any point of the product development process, raising the question about the right timing of involvement. This is illustrated in figure 2.9.

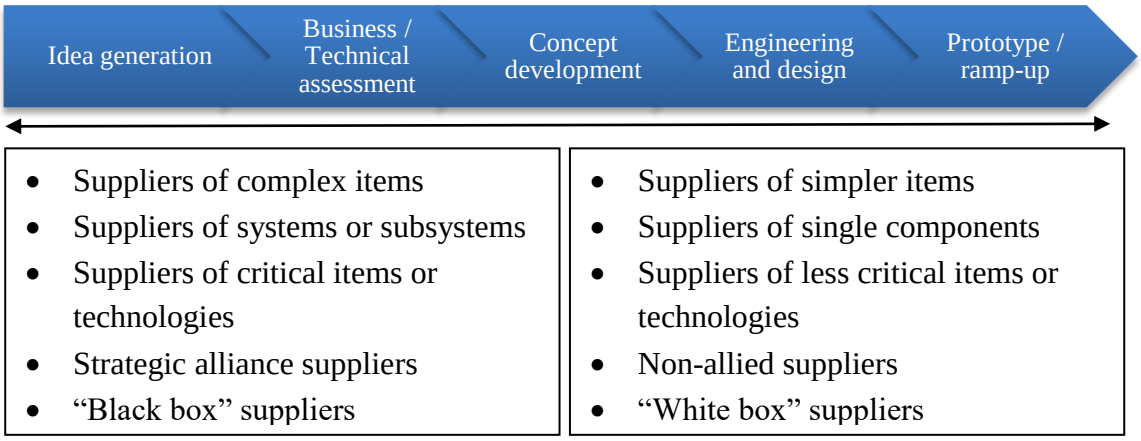


Figure 2.9. *Involving suppliers at different stages of NPD process (Adapted from Handfield et al. 1999, p. 78)*

Literature gives several suggestions about the factors that are connected to the timing of involvement. They suggest that the factors it depends on are the rate of change in the technology in question and the supplier's expertise in the technology. If the technology is changing fast in the markets it may be viable to involve the supplier later in the process. In terms of technology, complexity and criticality of an item are factors that are related to the timing of involvement as suppliers of more complex and critical items are typically involved earlier. Supplier profiles that are typically involved earlier are black box suppliers and strategic partners as opposed to white box and non-allied suppliers who are involved later. (Handfield et al. 1999, pp. 77-78.)

As opposed to the other studies, Hartley et al. (1997) and the findings of Wagner and Hoegl (2006, p. 940) suggest that all suppliers should be involved as early as possible. The question then is when it is possible to involve a supplier. McGinnis and Mele Vallopra (1999, p. 14) suggested that suppliers should be involved when they are needed. This would, however, support an assumption that it may be challenging to determine in advance when a certain supplier should be involved but instead the need may emerge during a project.

Wasti and Liker (1999) studied the factors that drive companies to practice early supplier involvement when outsourcing their design efforts therefore focusing on the decisions regarding develop-or-buy instead of make-or-buy. The study focused in the Japanese automotive industry but stated that the findings could apply to other contexts

as well especially when time is of the essence such as it typically is with concurrent engineering. The level of supplier involvement can be seen as a function of three variables: supplier's influence on the customer's design related decisions, customer's control over design specifications and the frequency of communication between the customer and supplier. (Wasti & Liker 1999, p. 352). The study proposed that impacts on the mentioned three variables and therefore the overall level of involvement can be attributed to product characteristics, supplier capabilities and buyer-supplier relationship characteristics. (Wasti & Liker 1999, pp. 352-353.) The main factors that determine the extent to which the supplier should be involved are in-house technical capabilities of suppliers and technological uncertainty of the part. Suppliers that are looking to achieve partnership status should develop capabilities to take on increased responsibilities in development projects. If a supplier who supports the buying company in new product development subcontracts prototyping, design work, analysis or testing efforts it might serve as a red flag proposing that the supplier is not capable of carrying their responsibilities. Regarding relationships it was stated that history and existing business with the supplier should be considered when assessing the risks of outsourcing design and with well-known suppliers who are dependent of the buying company the risk would be reduced. (Wasti & Liker 1999, p. 353).

Mikkola and Skjoett-Larsen (2003) studied how outsourcing and the level of interdependence between the buying and supplier company influence ESI in NPD. Their study suggested that a company should make its design insourcing and outsourcing decision by assessing its own capabilities in relation to its potential supplier partners. Supplier relationship influences the decisions regarding giving suppliers increased design responsibility instead of only giving responsibility based on outsourcing core competence. Product architecture design strategies influence decisions regarding the amount of responsibility given to suppliers since modular designs with standardized interfaces support outsourcing design work to suppliers while it is more challenging with integral architectures (Mikkola 2003). Additionally, the complexity and decomposition of a product were seen to influence the timing of involvement. (Mikkola & Skjoett-Larsen 2003, pp. 37-38.) Kamath and Liker (1994) suggested that buying companies should determine whether they are consistently handling components of certain complexity and determine the most suitable supplier role for these components given the capabilities of the suppliers of those typical components.

Compared to the framework presented by Petersen et al. (2005) the model by Laseter and Ramdas (2002) distinguishes the connection between different types of products and specifications a developed part may have with the level and timing of integration. The specifications can be physical, functional or mixed. The number and complexity of the interfaces that the part or systems have were also seen as influencing features. Additionally, value add provided by the part or the cost caused by it should also be considered as influencing factor with regard to the level of supplier involvement as well as the nature of interaction between the buying company and supplier. In terms of the

timing a difference was made regarding the initial moment of involvement and how the role of the supplier continues after that: declining, continuous and lagged iteration. (Laseter & Ramdas 2002, pp. 116-117.) Therefore the supplier's role may not remain consistent throughout the project.

Also Clark (1989) found part related influencing factors. The study discussed the effect of number of unique parts versus common and carryover parts and ESI to project. High number of unique parts was found to be related to high amount of supplier involvement which makes up for a significant portion of cost and lead time advantages. (Clark 1989, pp. 1260-1261.) Therefore parts strategies have an effect on ESI since companies may have different emphasis regarding designing unique parts as opposed to striving to utilize common commercial or previously utilized carryover parts.

Parker et al. (2008) suggested that several project specific factors have a relation to the extent and timing of involvement. The emerged need for new technology in a project was found to be connected to involving the suppliers earlier. Moreover, strong prior relationships with a supplier and the strategic importance of the supplied part also had a positive correlation with earlier involvement while the timing of involvement was surprisingly not found to be linked to strong prior experience between the buying and supplying companies. Finally the timing of involvement itself was found to be have a significant influence of project success supporting the idea that suppliers of different items should be involved at different phases and to different extent. (Parker et al. 2008, pp. 79-80.)

In their study based on cases in five companies, Wagner and Hoegl (2006) sought insights from R&D directors and project managers regarding managing ESI in new product development projects. They found several considerations that are made in those companies. Different projects: know-how and capacity and different typical characteristics of involvement in these cases, criteria for supplier selection, buyer supplier relationship, timing of involvement, project level: size and configuration of project team.

Le Dain et al. (2010) presented an approach to making design-or-buy-design decisions in product development projects. This approach includes evaluating the development risk of each part as a function of several criteria regarding not only technological and design risks but time, costs and supply chain complexity related risks or criticality as well. This would give an idea about the desired level of supplier involvement as compared to the risk and striving to select a supplier that is capable of providing support to the wanted extent. If such supplier does not exist in the supply market or the buying company does not have enough resources to coordinate the deep involvement of several suppliers regarding the same project compromises would need to be made regarding the extent of involvement. (Le Dain et al. 2010, pp. 81-86.) The key takeaways of this approach is that when evaluating the design risks or need for involvement not only the

internal capabilities of the case company and technological complexity and challenges should be evaluated but also time, cost and supply chain criticality may be reasons to involve suppliers early. Moreover, a buying company might not have suppliers that could be involved to the most wanted extent. It also needs to be kept in mind that involving several suppliers greatly increases the amount of coordination, communication and management between organizations.

Several factors to consider regarding the moment and extent of involvement were recognized. Having covered these factors it should then be assessed what type of coordination activities are required to manage the collaboration with suppliers.

2.2.6. Coordinating ESI collaboration

It is essential to recognize between different forms of supplier involvement so that companies can coordinate the collaboration with a suitable amount of communication and information sharing. It can be argued that how the collaboration will be coordinated is influenced by the previously presented factors but there are also specific factors that need to be considered in this coordination.

Wynstra and Ten Pierick (2000) proposed a framework that takes into account two dimensions in determining the coordination of involvement for each situation: the degree of responsibility held by the supplier and the degree of development risk. The framework suggests that each combination in the matrix should be managed differently in terms of how much communication takes place, how and what information is shared and between whom. The vertical axis can be considered to be the same as in the spectrum of supplier involvement presented before and the horizontal axis depends on development risk that relates to several factors. (Wynstra & Ten Pierick 2000, pp. 52-53.) The degrees of different responsibilities and the risk factors were covered in the previous section since the risk factors can be considered to consist of the factors that affect decisions regarding what kind responsibility to give a supplier. The matrix is presented in figure 2.10.

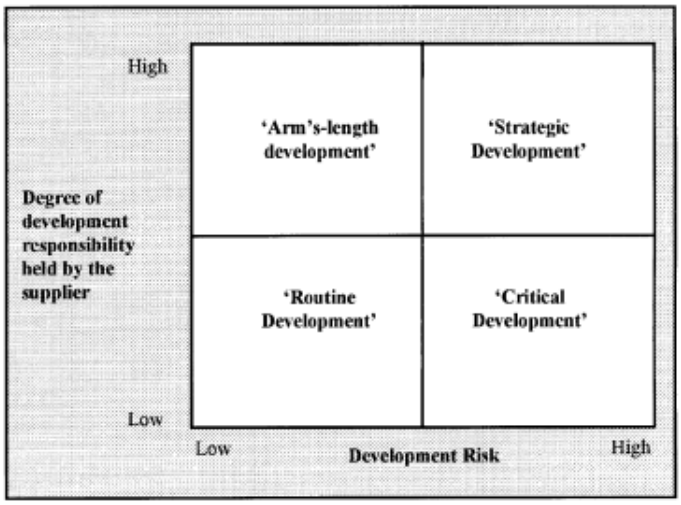


Figure 2.10. *The supplier involvement portfolio (Wynstra & Ten Pierick 2000, p. 51)*

Wynstra and Ten Pierick (2000) also suggested that the different blocks in the matrix should be managed in different way in projects in terms of communication. The differentiated communication approaches are presented in figure 2.11.

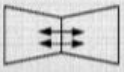
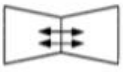
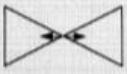
	Strategic Development	*Critical Development*	*Arm's-Length Development*	*Routine Development*
Kind of Collaboration	Close co-operation as 'sparring partners'; Joint development	Focus on obtaining information	Independent development by supplier	Informing each other about changes
Direction of Communication	'Two-way traffic'	'One-way traffic'; at manufacturer's initiative	'One-way traffic'; at supplier's initiative	'Two-way traffic'
Communication Medium	Rich media such as face-to-face group meetings	Lean media such as telephone and fax	Rich media such as face-to-face meetings	Lean media such as fax, mail and e-mail
Amount of Communication	High	Medium	Medium	Low
Functional Disciplines	Diverse	Purchasing/sales (and development)	Development (and purchasing/sales)	Purchasing/sales
Content of Communication	Technical and commercial information	Market (and technical) information	Technical (and status) information	Status information
Communication Structure				

Figure 2.11. *Communication guidelines in different collaboration relationships (Wynstra & Ten Pierick 2000, p. 56)*

The figure suggests that the higher the design risk is and the more responsibility the supplier has, the more communication is needed through richer media, the more comprehensive information should be shared and the more people should be involved in the communication. The right approach should be selected on a project level to avoid committing resources to extensive communication especially if the development risk is low and supplier's responsibility is low. (Wynstra & Ten Pierick 2000, pp. 54-56.)

As stated earlier in this study, it may be an effective way to coordinate the collaboration by utilizing engineer co-location. Especially in cases of high technological uncertainty it appears to be beneficial to make supplier representatives part of the development team through co-location or frequent meeting participation. Suppliers' technology roadmap should be included in the development cycle to prevent selecting technologies that will become obsolete and ensuring achieving target costs. This way reductions in concept to customer development time and improvements in quality can be achieved (Ragatz et al. 2002, p. 398). With regard to the communication figure above it could be assumed that co-location would come into question especially when the supplier's responsibility is high.

Fliess and Becker (2006) presented processes for managing co-development with the suppliers based on 12 case studies. Their study suggests that the co-development activities with the suppliers and coordination methods are different in different stages of product development process. The suggested tasks and means of coordination are presented in table 2.4. Additionally, the form of cooperation varies between different degrees of innovation, know-how position of the customer and clarity of specifications. (Fliess & Becker 2006, pp. 41-42). The coordination activities and supplier activities should be in line with the buying company's development process phases. This is a more practical approach than simply stating that supplier should be involved at a certain point but instead the viewpoint is to look at the actual tasks and ways of coordinating the collaboration at different phases.

Table 2.4. *Product development collaboration coordination methods and intruments at different stages of product development (Fliess & Becker 2006, p. 41)*

Stage	Coordination task	Instruments / means of coordination
Concept stage	Define interfaces (personally and technically) Coordination of expectations and possibilities Shaping property rights	Meetings (Written) proposal Patent analysis
Detailed	Coordination of activities according to goals	

engineering stage	Coordination of activities according to costs	
	Early warnings on cost deflections or matching costs and target price	Concurrent calculation, project monitoring
	Coordination of activities according to product quality. Early warnings on product functionality / quality deflections	Checklists Product audits FMEA (failure mode and effect analysis) Function tests Prototype
	Coordination of activities according to time. Early warnings on time deflections	Activity list Milestones Project plan
Process engineering and product introduction	Avoiding or minimizing risks during regular production	Know-how transfer by product documentation and training Estimation of lot size First sample examination

Lakemond et al. (2006) studied six product development projects and proposed contingency factors that should be taken into account in selecting the right approach for a necessary degree of supplier coordination. The fundamental idea of their study was that there is no single best method for coordinating ESI and therefore different approaches and the factors to consider need to be recognized. The three coordination methods recognized are project integration coordination, disconnected sub-project coordination and direct ad-hoc contact. Project integration coordination is about the supplier becoming a part of the project with continuous and frequent interaction throughout the project. Face-to-face collaboration and co-located employees might be good strategies for this type of coordination but it is not a necessity if similar information sharing and exchange can be achieved by utilizing information technologies. Disconnected sub-project coordination is suitable when the supplier is formally assigned with a task that they can carry out rather independently of the buying company's project. Such approach might come into question when dealing with rather independent modular units which are part of the end product and it is the least time and effort consuming coordination method. Direct ad-hoc coordination, on the other hand, is a more informal way of coordinating as the idea is that the technical or sourcing directly

contact their counterparts at the supplier on ad-hoc basis. It is implied that while this type of collaboration might not be continuous throughout the project it still requires good relationship between the two companies. Additionally several of these methods or a combination of them may be used with one supplier during a project. (Lakemond et al. 2006, pp. 60-61.) The different coordination approaches are presented in figure 2.12.

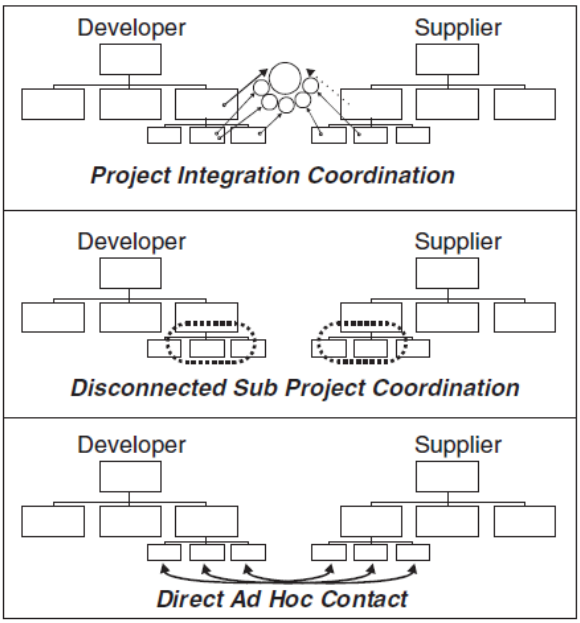


Figure 2.12. *Different coordination approaches for supplier involvement in new product development projects (Lakemond et al. 2006, p. 60)*

The variables that define which coordination method would be most suitable were found to be the degree of task dependence, degree of diverging expectations and existence of long-term collaboration objectives. Task dependence relates to the tasks carried out by the buying company and by the supplier as evaluated on the basis of task complexity and technological novelty. Diverging expectations and long term that these ESI coordination methods may be utilized also to bring the companies closer and develop a common way of working together. The intention with each coordination method might not only be short term efficiency but also long term learning. (Lakemond et al. 2006, pp. 62-63.)

It needs to be kept in mind that in R&D collaboration trust might not be enough when two companies do business together and therefore a certain balance needs to be achieved through trust and contracting in governing the ESI collaboration. In fact, trust and contracts can be seen as complementary instead of being contradictory. Blomqvist et al. (2005) studied balancing this collaboration with trust and contracts and suggested that contracts and contracting process play an important role in building trust between companies and operate as structured means of articulating goals, expectations in an explicit way. Additionally contracts communicate continuity regarding collaboration as well as diminish risks for major disagreements during product development

collaboration and protecting the companies' proprietary information in general. Contracts do not guarantee success in ESI collaboration and it would be risky to only base the collaboration on trust but together these two work as complementary tools to enable fruitful collaboration. (Blomqvist et al. 2005, pp. 501-502.) It could be argued that the existence of comprehensive long-term contracts also facilitate trust between the companies therefore supporting the collaboration in NPD.

In fact, trust and partnership type of relationship might not exist in all projects while there might still be a need for some form of early supplier involvement. A distinction can be made between different types of ESI business models based on this. Eisto et al. (2010) studied ESI in the casting industry and proposed a network collaboration model. The model distinguished between three different levels of collaboration that are differentiated in terms of business model, opportunities in making changes to the design based on supplier input, communication and defining supply network's role in the product development process and contracts. Business model refers to the proposal that different forms or levels of ESI collaboration should be compensated to the supplier in different ways and suppliers would be selected based on different criteria. The closer the collaboration, the more the business model should be based on trust and sharing risks and rewards while with less close collaboration the compensation could be based on paying for design work. (Eisto et al. 2010, pp. 736-738.) This approach takes into account the situations that although it has been deemed most recommendable to do close ESI collaboration with the trusted suppliers, companies also may need to involve other suppliers early. In these cases the approach will be rather different as it is not based on partnership but rather on transactional ad-hoc needs.

A distinction can be made based on whether the governance of collaboration is based on transactional or relational collaboration as presented above. Melander and Lakemond (2015) studied the governance of supplier collaboration in technologically uncertain projects and found that the approach greatly different from a project with low technological uncertainty. Governance may be transactional or relational based on the level of uncertainty. In technologically uncertain project more attention may need to be put into safeguarding proprietary information, protecting the company from suppliers' opportunistic behavior and remaining flexible to changes while avoiding getting locked in to a certain supplier. This type of governance is a more transactional approach. (Melander & Lakemond 2015, pp. 124-125.) This can be attributed to the need for involving suppliers of new technologies with whom the buying company does not have existing business and therefore no close and trust-based relations and benefits of existing business and experience.

It would be oversimplifying regarding supply chains and networks to only consider the coordination activities between two companies. As suggested by Wynstra et al. (2003) not only coordination activities with single first tier suppliers should be considered but instead a company may need to coordinate the collaboration with several first tier

suppliers and second tier suppliers. Johnsen (2011) studied so called delegation and intervention strategies where the aim is to access and involve the indirect suppliers of the supply network during NPD. Delegation is about empowering the direct suppliers and giving them the main responsibility of managing the indirect suppliers. This could be a fitting strategy for modular designs and the activities from the buying company in this strategy could include for example encouraging the suppliers to communicate and solve problems with their own suppliers or simply trusting that the supplier takes care of what is required. The intervention strategy on the other hand is about the buying company taking a more firm control of the supply chain by for example defining which sub-suppliers can be uses, communicating and buying directly from the sub-suppliers and connecting the sub-suppliers to each other to share information and solve problems. This strategy may come into question especially regarding critical parts or it may be helpful in better managing the costs in NPD. This may, however, lead to the supplier feeling constrained by the sub-supplier selections by the buying company. (Johnsen 2011, pp. 700-703.) It can therefore be stated that the form of the supply network and the needs to coordinate the collaboration with sub-suppliers also has an effect on managing ESI practices. Delegation strategy would require the direct suppliers to be able to actively manage their own supply network whereas intervention would require more active supply chain management from the buying company. The different strategies are illustrated in figure 2.13.

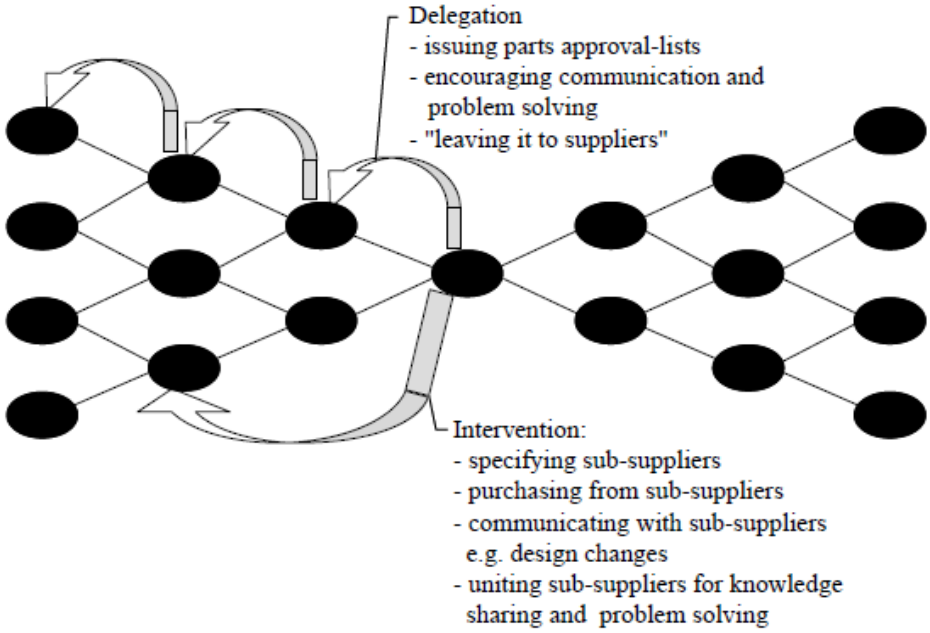


Figure 2.13. *Different methods for supply network delegation and intervention (Johnsen 2011, p. 701)*

Johnsen and Ford (2007) studied the factors that influence whether companies apply active delegation or intervention strategies to control their supply chain. Their study suggested that the degree of influence and power that the buying company has in

relation to its supply network has an effect on the use of these strategies and companies with high power are more likely to utilize such strategies. Additionally, the lack of trust in the suppliers' capabilities led to more intense coordination. Moreover, the modularity of product architecture and the criticality of parts in terms of strict specifications were found to lead to more intense use of these practices. (Johnsen & Ford 2007, p. 306.) Therefore similar influencing factors shape the form of coordination as the factors that influence the extent and moment of involvement.

As has been discussed, it is possible that a company has the need to involve numerous suppliers to its new product development project. Andersen and Drejer (2009) studied the effects that involving multiple competing suppliers into a project has on managing ESI. They discovered that involving competing partners to the same project influences the level of openness in communication and sets certain limits to the way in which the collaboration can be arranged (Andersen & Drejer, p. 801). Therefore in addition to requiring more coordination in a project if several suppliers are involved to rather high extent, it needs to be kept in mind that the dynamics of the supplier mix involved may influence the collaboration due to competitive reasons.

As a summary it appears that several factors need to be taken into account in determining the most fitting method of coordinating the co-development collaboration with the suppliers. The activities carried out by the supplier are dependent on several things and should be aligned with the activities of the buying company. It needs to be kept in mind that there might not be a necessity to involve only one supplier but instead the coordination and is made more complex and challenging if several suppliers are involved.

2.3. Combining the theories: Factors that shape the need and form of Early Supplier Involvement

This synthesis of the theories also provides the starting point for the empiric research. That is, first the current state and ideas are recognized and then the influencing factors related to managing ESI. A company first needs to identify its current practices and overcome the barriers to ESI, then establish the prerequisites that enable ESI and aim towards the establishing the success factors in its practices. It is necessary to understand both the organizational factors and the project specific factors as the factors can be used to determine how ESI should be managed at a company. A conceptual framework covering several factors that influence managing ESI based on literature is presented in figure 2.14.

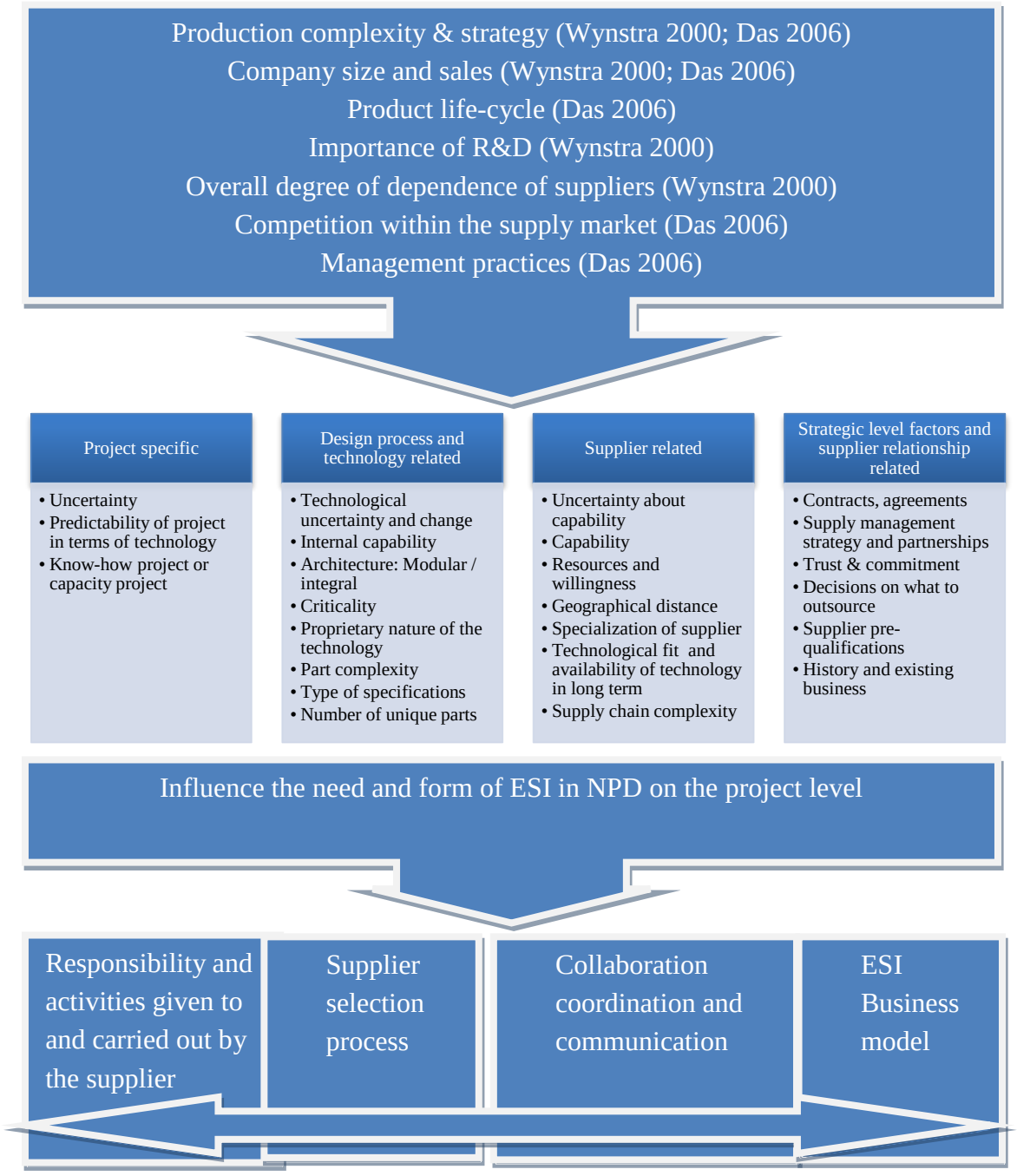


Figure 2.14. *A conceptual framework: factors that influence the need for ESI and form of managing ESI in product development projects*

The organizational factors can be seen as a root cause for the project level factors that determine the type of approach that is most suitable. The organizational factors can be seen as rather permanent or slowly changing factors that have an overarching effect on the type of products the company produces, way of producing them and the supplier base. Regarding this study it is useful to understand the organizational factors although they are not the focus of this study. Of more interest are the factors that vary from project to project and what are the basis of decision making in practice.

The project level factors found from the literature are categorized to four categories which are project related, part design process and technology related, supplier related and strategic level and supplier relationship related factors.

Project related: Factors that can be directly connected to a project's nature can be found from literature. McIvor et al. (2006) stated that the predictability or unpredictability of a project has implications regarding ESI. Wagner and Hoegl (2006) suggested a distinction between so called 'know-how projects' where supplier knowledge is utilized in innovative projects in rather close collaboration, and 'capacity projects' where suppliers are given responsibility of less critical parts and systems for capacity (human resource) reasons. These can be seen to be closely related to the type of new product development project in question and uncertainty which has been studied by Melander and Tell (2014). These factors are more likely to be more clearly manifested on the part design and technology level but the type of project in question already gives indications regarding ESI considerations.

Design and technology related: Key considerations should be made on part and assembly level since viewing the project as a whole is not specific enough to recognize factors related to design and technology related aspects in relation to internal capabilities. Internal capability to develop and design certain technologies as compared to a supplier's capability is in a key role when considering giving suppliers' responsibilities (Handfield et al. 1999). Uncertainty appears to be one of the main factors to consider in managing ESI as the amount of uncertainty influences all ESI decisions and approaches (studies involving Melander). Architecture (modular or integral) has implications regarding ESI since modular designs and separate modules are easier to outsource and suppliers can potentially act more independently on a separate module (Mikkola & Skjoett-Larsen 2003). High number of unique parts versus number of common and carryover parts is connected to higher levels of ESI (Clark 1989). Complexity of the part and number of interfaces and the type of specifications (physical, functional or mixed) should be considered since more complex parts and functional or mixed specifications appear to be connected to deeper ESI activities (Laseter & Ramdas 2002). Proprietary nature of technology in development may limit information sharing (Handfield et al. 1999). Value add or cost effect of the part should be considered as affecting factors (Laseter & Ramdas 2002; Le Dain et al. 2010). Technological change regarding the technology in question should also be considered in relation to the product life cycle (Handfield et al. 1999).

Supplier related: The supplier related factors to consider are highly related to a set of capabilities (cost, quality, schedule, innovative capability, relational) which are all factors influencing ESI management (Handfield et al. 1999; Wasti & Liker 1999; Le Dain et al. 2011; Petroni & Panciroli 2002). Lack of trust in supplier's capability and lack of information about them (Johnsen & Ford 2007; Melander 2014) also influence collaboration with suppliers. Availability of suppliers' resources and their willingness to

provide them are factors to be considered in managing ESI in a certain project (Wynstra et al. 2001). It should be considered whether the supplier is specialized in certain type of technology or is a more generic contractor as it is more likely for specialized suppliers to possess innovative capabilities. (Schiele 2006). Geographical distance has implications regarding the ease of collaboration and coordination (Schiele 2006) as does supply chain complexity since information and deliveries flow slower through complex supply chains (Le Dain et al. 2010).

Strategic and relationship related: Strategic considerations within a company as well as supplier relationship factors have an effect on managing ESI although the project is managed on the operational level. Trust and commitment in the supplier relationship are important factors as they enable closer collaboration (Walter 2003). This is supported by existing contracts and agreements (Ragatz et al. 1997; Blomqvist et al. 2005). History and existing business with a given supplier have effects on managing ESI on the project level (Wasti & Liker 1999). Buying company's portion of supplier's revenue and partnership status have implications on ESI management (Schiele 2012). This is related to the supply management strategy referring to the mechanisms of how a company manages their suppliers (McIvor et al. 2006). Alignment of technology roadmaps referring to availability of needed technology at the supplier should be considered on the strategic level influencing decisions on project level (Handfield et al. 1999). Moreover, strategic development decisions about what design work to outsource, which suppliers have been pre-qualified for ESI collaboration, partnerships and supplier development efforts have effect on ESI decisions on the project level (Van Echtelt et al. 2008).

It is likely that the importance of each factor varies case by case and the importance can also be attributed to the overall goals of involvement: whether the goal is short term efficiency or long term learning (Lakemond et al. 2006), reducing costs, improving quality, reducing lead time or reducing supply risk in general (see Zsidisin & Smith 2005). It is possible that there are only few key driving factors that among the factors presented which have the most significant influence on the approaches chosen.

The project specific factors determine the need for early supplier involvement and the form of managing it. The form of early supplier involvement in the model is summarized to consist of four blocks: the responsibilities and activities of the supplier, supplier selection process, collaboration coordination and communication and business model. The blocks are connected to each other since they should be aligned. For a certain need there should be a suitable amount of activities that the supplier is responsible for, a suitable supplier with the needed set of capabilities and resources, the fitting business model on how to reward the supplier of participation and the suitable amount of communication and collaboration coordination during the project. These blocks are summarized below and can be found in table form in appendix 3.

Supplier's responsibility and activities: The supplier's responsibility and role may differ and accordingly the tasks they carry out may be different. The responsibility may vary from no involvement at all to holding the main design responsibility. The tasks required from the supplier are different at different phases of product development and may vary depending on the role of the supplier.

Supplier selection process: The factors have an effect on how the supplier is selected. Based on the research selecting the supplier for involvement can be a rather straightforward process if the suppliers are already known or pre-qualified or so called preferred suppliers. On the other hand especially in cases of technological uncertainty the selection process might not be so simple since companies attempt to remain flexible and avoid selecting a technology too early. It is even possible to involve the suppliers in the selection process by challenging them to propose solutions in concept competition. There should be several criteria in selecting the supplier with the focus on total costs. Knowledge about the supplier and their capability with regard to the design is in key role.

Collaboration coordination and communication: Regarding collaboration coordination and communication decisions are made regarding the frequency and media of communication, the information shared and the people involved in communication. A specific set of collaboration coordination methods should be selected for each case whether it is ad hoc direct coordination, integrated coordination, decoupled coordination or a combination of them. The coordination activities are different at different phases of product development. The coordination may include managing second tier suppliers by delegation or intervention. The coordination may include balancing between contracting and trust as well as coordinating collaboration with several suppliers that may even be competitors with each other.

Business model: ESI business model relates to the logic of how to motivate the supplier to participate in the buying company's new product development. Although it has been found that ESI is typically most successful when done with partners, there may be cases when new suppliers are needed for a project. This type of ESI is not based on partnership, mutual trust and long history and therefore paying for consultation or design work might come into question. The business model is related to whether the collaboration is transactional or relational: with relational collaboration there is continuity between the two companies regardless of the specific project. Especially in cases where the supplier is new and trust based relationship does not exist and technological uncertainty is present, it may be likely that paying for consultation is a feasible way to proceed especially if the company is not willing to commit to that supplier and technology right away.

In the results chapter these factors and their presence will be compared to the case company's context based on the research to determine the most suitable model.

3. RESEARCH METHOD AND MATERIAL

3.1. Research strategy and methods

The need for the study stemmed from the case company's need to establish systematic ESI practices and therefore the research objective and research questions are based on the company's particular need. The research strategy was designed and the methods were chosen to best enable achieving the objectives and answering the research questions. According to Saunders et al. (2009, p. 109) this type of research philosophy represents pragmatism which claims that the main determinant for the chosen research strategy and methods is the research question. Pragmatism implies that mixed or multiple method designs would come into question. (Saunders et al. 2009, p. 119.) The study focuses in developing the practices of one case company making it a single case study.

The research approach of this study is mainly inductive as it aims to construct theory based on gathered data (Saunders et al. p. 124). This approach was chosen because it was important to understand the nature of the research problem and seek for several opinions and points of view in the particular context of the case company. The company's context in terms of ESI was poorly covered in literature and therefore directly testing existing theories at the case company's context might not have served the objective of the study. Nonetheless, the existing models were utilized to seek ideas and reference points. According to Saunders et al. (2009, pp. 124-125) inductive approach provides a more flexible approach to the research process in comparison to deductive approach where theory is tested through research. Inductive approach also recognizes that the researcher influences the research process as a part of it and the approach is less concerned about providing highly generalizable theories which is suitable for the pragmatic philosophy. (Saunders et al. 2009, pp. 124-125.) Saunders et al. (2009, p. 127) state that it is both possible and often beneficial to combine features of both induction and deduction approach within the same study. This study utilizes such approach since there is a great deal of interplay between theory and practice. Due to the big amount of iteration the approach could also be described as to contain elements of abductive reasoning (Dubois & Gadde 2002).

The approach is implemented as action research meaning that the researcher is part of the case organization where the change process takes place. The research is conducted in action among an organization's members who are directly affected by the phenomenon under study. Action research fits the research objectives and questions of the study since it is characterized by a focus towards organizational change, is iterative

by nature and enables involving the relevant stakeholders in the research process. (Saunders et al. 2009, pp. 147-148.) The iterative nature of action research in this study is presented in figure 3.1. The iteration includes getting to know the company, gathering ideas from literature with the case company in mind, evaluating the findings and acting upon the feedback received from the supporting groups.

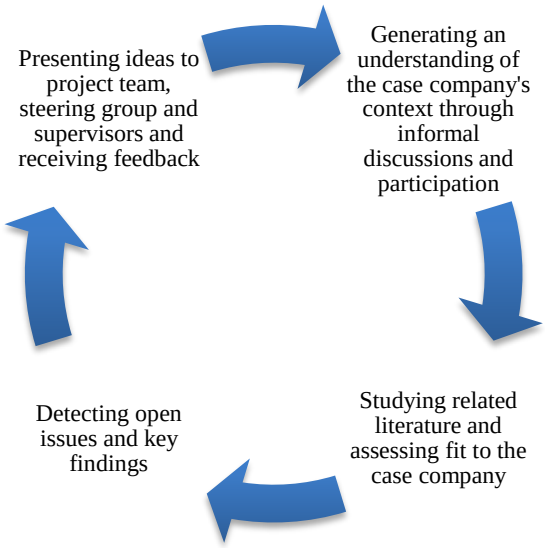


Figure 3.1 *Depiction of the iterative action research in this study*

As proposed by pragmatism, multiple methods were chosen in order to receive data by more than one way and to more effectively involve the main stakeholders in the creation of ESI practices. In this research multiple qualitative methods were applied making it a multi-method qualitative study (Saunders et al. 2009, p. 152). According to Saunders et al. (2009, p. 153) multiple methods come into question if they better support answering the research questions and may be beneficial especially in different phases of the study. Much like in this study, in the beginning interviews can be utilized for exploration, generating an understanding and then build upon that knowledge while going deeper into the research topic with another research method. Due to the high number of stakeholders related to the topic it was essential to gather data from a rather diversified audience but on the other hand the stakeholders needed to be approached in different ways. The approaches were therefore tailored specifically for the audiences and allowing for more open and fruitful discussion. For this purpose, semi-structured interviews and workshops were selected to most efficiently support developing the ESI model. The methodological research choices made in this study are presented in figure 3.2.

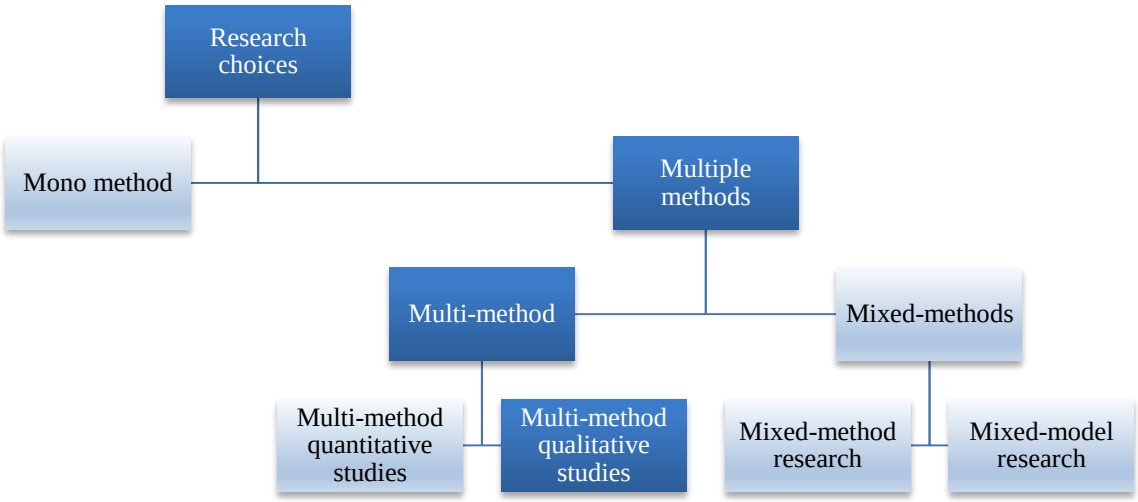


Figure 3.2 *The research choices in this study (Adapted from Saunders et al. 2009, p. 152)*

The whole population of potential participants for the research was unmanageable to study within the limits of this research and therefore sampling techniques needed to be applied. The sampling techniques used in this study can be classified as non-probability sampling since the statistical chance of an individual being selected in the sample could not be defined. More specifically, the sampling for both the semi-structured interviews and workshops can be described as purposive sampling where the most suitable cases in terms of best answering the research question were selected. (Saunders et al. 2009, pp. 212-213; 237-240.) The potential participants were considered, suggested and agreed upon among the members of the steering group.

In the big picture, the research strategy was designed in an aligned way to best answer the research questions that were derived from the case company's needs. Among the research strategy choices made there appear to be no contradictions as each selection is supported by the upper level selections. However, quantitative methods could have been considered as part of the research to generate statistical data from a broader audience. Due to the context of the case company, the broadness of the topic and the fact that the research aimed at driving change it was seen more beneficial to apply qualitative methods where the participants can interact and articulate their thoughts in a less structured manner. The whole research strategy and methods of this study are summarized in figure 3.3.

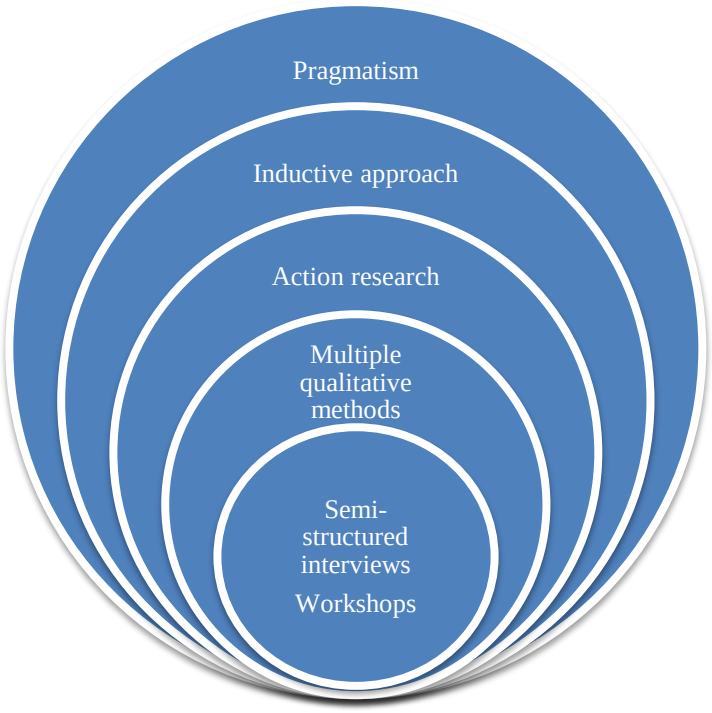


***Figure 3.3**. This study presented in the research onion (Adapted from Saunders et al. 2009, p. 108)*

The semi-structured interviews were conducted during June-July 2015 by the researcher with the intention of recognizing the current state and practices of the case company as well as discovering the thoughts, expectations, interests and challenges regarding ESI at the case company. Additionally, several of the case company's main suppliers were interviewed about the same topic. The rest of the research took place between October 2015 and March 2016. During this time the workshops were conducted and the researcher took part in two product development projects to learn about the projects and to consider ESI in those projects. Additionally, information was gathered by taking notes from informal discussions. The research process and the methods used at different times are presented in figure 3.4.

Method	2015						2016		
	6	7	8	10	11	12	1	2	3
Action research									
Semi-structured interviews									
Workshops									

***Figure 3.4.** Timeline of the research process and methods*

The thesis was written mostly between December 2015 and February 2016.

3.2. Data collection and analysis

The goal of the case company was to describe and establish systematic practices for ESI in NPD. As NPD is a team effort especially due to the nature of concurrent engineering, it was the most natural approach to involve the most relevant stakeholders in gathering data related to the issue. It was also important for the researcher to establish a personal contact with the research participants, learn the attitudes and ideas that the respondents have and understand the context of the case company. For this purpose face-to-face semi-structured interviews are a suitable option (Saunders et al. 2009, pp. 323-333). The idea of semi-structured interviews is that the researcher has a list of themes and related questions that can vary in different interviews. Also the order of the questions may vary depending on the flow of discussion and additional questions may be presented when needed. (Saunders et al. 2009, pp. 320.)

Although several stakeholders were also interviewed it was seen as highly beneficial to have them ponder the things with each other in workshops. This approach allowed participants to hear and discuss each other's opinions and experiences about ESI practices in more detail. This way the practices could be discussed and agreed upon among the same people who might actually be working together in a product development project. Therefore it would most likely result in higher acceptance from a greater audience and the willingness to adopt the practices might prove to be increased as the issues have been discussed together. The workshop approach is aligned with the purpose that ESI practices should not be forced by only one department but instead it should be a joint endeavor for the benefit of the company. As workshops are not among the most common methods for gathering data, the process of workshopping will be described in more detail. Especially with the interviews it appeared that enough people were interviewed since the data became saturated with no significant new points of view surfacing.

Studying the theory was done simultaneously while planning the research process in an iterative fashion. Therefore the theoretical part of the research acted as a starting point while collecting data from the interviews. After the interviews had been conducted and the theory studied, the workshops were conducted to answer the open issues. The theories and research methods were selected in interplay while both were chosen on the basis of the research objectives and questions.

The data gathered is qualitative which is characterized by meanings expressed through words instead of numbers as well as the need for categorization and conceptualization in analysis work (Saunders et al. 2009, p. 482). Therefore known methods for analyzing qualitative data were applied. In this study all main three types of qualitative data

analysis processes are used: narrative, categorization and summarizing. (Saunders et al. 2009, pp. 490-491.)

3.2.1. Semi-structured interviews

A total of 14 employees of the case company were formally interviewed. Additionally, representatives of 11 of the case company's main suppliers were interviewed. List of the participants can be found in appendix 1. The suppliers represented mechanics manufacturing, EMS's and cable and harness manufacturing. More specifically the mechanics suppliers represented machining, sheet metals, injection molding, and packaging. All of the suppliers selected for the interviews were the case company's preferred suppliers or otherwise deemed relevant by the research project team and the people interviewed were ones that work closely to customers' new product development projects. The semi-structured interviews gave the researcher a broad idea about the viewpoints of main related stakeholders and the issues that the case company faces. The interviews dealt with the benefits, challenges, risks, prerequisites, current and typical practices, good practices, expectations and wishes regarding ESI. The people from within the case company were chosen based on the recommendations of the steering group participants. Mainly mechanical engineers and sourcing personnel were chosen as they were considered to be the most relevant stakeholders. The engineer interviews focused on mechanics as it was seen that in mechanics there is room for more improvement.

The interview structures were sent to the interviewees beforehand. The duration of the interviews ranged from 35 minutes to 1 hour 15 minutes. The interviews were conducted according to an interview agenda both within the case company and with the suppliers. The questions were tailored to match the interviewee's role and in accordance to the nature of semi-structured interviews the flow of interview had effect on the questions asked. The flow of the interview can be divided to three sections according to the focus of each part. The interview structure and themes is presented in figure 3.5.

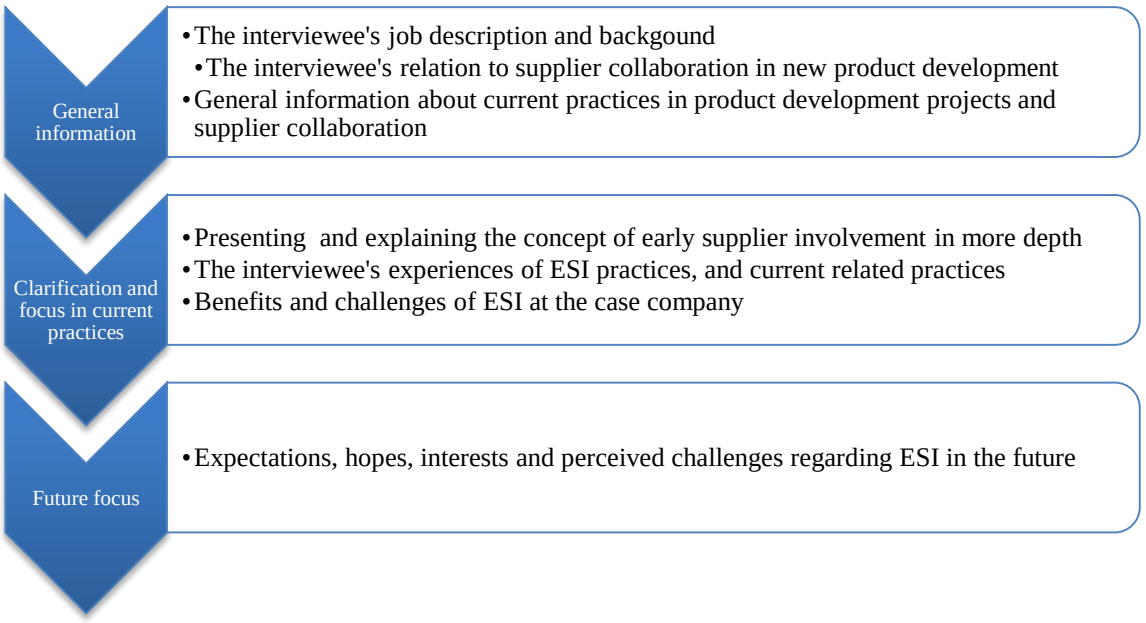


Figure 3.5 *The structure and process of the semi-structured interviews*

Most of the interviews were recorded, transcribed and then analyzed. Three internal interviews were not recorded but notes were taken during the interview and the notes were completed immediately after the interview. The analysis was based on rough categorization and the results are presented in narrative form.

3.2.2. Internal workshops

The workshops were planned with the aim of receiving further ideas and confirmation for the systematic model as well as to discover the factors that influence the need and form of ESI at the case company. Additionally good practices for the individual steps of the model were gathered from the participants' good experiences. The workshops took place after the new sourcing strategy had been introduced and the presence of ESI as one of the building blocks in the strategy was presented to the participants.

Preparations for the workshops began by setting the objectives for the workshops and determining the required participants. It was decided with the researcher's instructors from the case company that the workshops would be divided into two sets with the first set comprising only of people from the case company and the second set would include members of key suppliers as well. Accordingly, the first set of workshops would be focused on internal practices and considerations which would enable involving the supplier at an early phase of NPD. The second set would enable discussion about collaboration possibilities with the supplier and the related practices and considerations rather than merely considering it within the company.

The focus was first directed towards planning the first set of workshops. The objectives and potential participants for the first set were considered together with the researcher's support group and steering group. It was agreed that the first set would include people

from sourcing and R&D. The target groups were R&D project managers, mechanical engineers, electronics engineers, sourcing project managers and component managers. The participating people were proposed by the steering group members and the researcher on the basis of having representation from the relevant cross-functional stakeholders, experience at the case company, development mindedness and availability. Some of the participants had already participated in the semi-structured interviews as well.

The people were sent an invitation to the workshop by email two to three weeks before the planned events. The invitation included background information about the project and the motivation behind it as well as the purpose of the workshops. It also included an ESI related scientific article and a pre-task. The pre-task was to think about experiences of good practices related to ESI in the work of the invitee and to consider the benefits and challenges of ESI. The invitees were encouraged to read the article and asked to prepare to present their answers to the pre-task in the workshops. The invitation came with a request to confirm or decline the invitation so that other candidates could be contacted if necessary and the workshops could be better planned for a certain amount of people. A reminder about the pre-task was sent to the participants two days before the workshops.

The agenda, facilitation methods and tasks were based on the research questions and built around the preliminary requirements and building blocks for the model that were obtained from interviews, literature and informal discussions. The researcher acted as the facilitator for the workshops. The workshops started with the researcher presenting the background of the project and ESI activities at the company as well as the purpose and goal of the workshop. The participants were then asked to introduce themselves as not all of them had worked together before. This also worked as an ice-breaker to get the participants warmed up. The tasks, including the pre-task, were facilitated by introducing the task and its goal to the participants followed by individual thinking and writing on post-it notes. The tasks focused on rather broad topics and therefore a set of helpful questions related to the task were presented to the participants to help focus on the relevant issues. The participants were asked to consider the tasks especially from the viewpoint of their own work role. The individual thinking results were then presented individually followed by group discussion around the given task. More details were asked during the discussion by the participants and the researcher. The process and activities during the workshops are presented in figure 3.6.

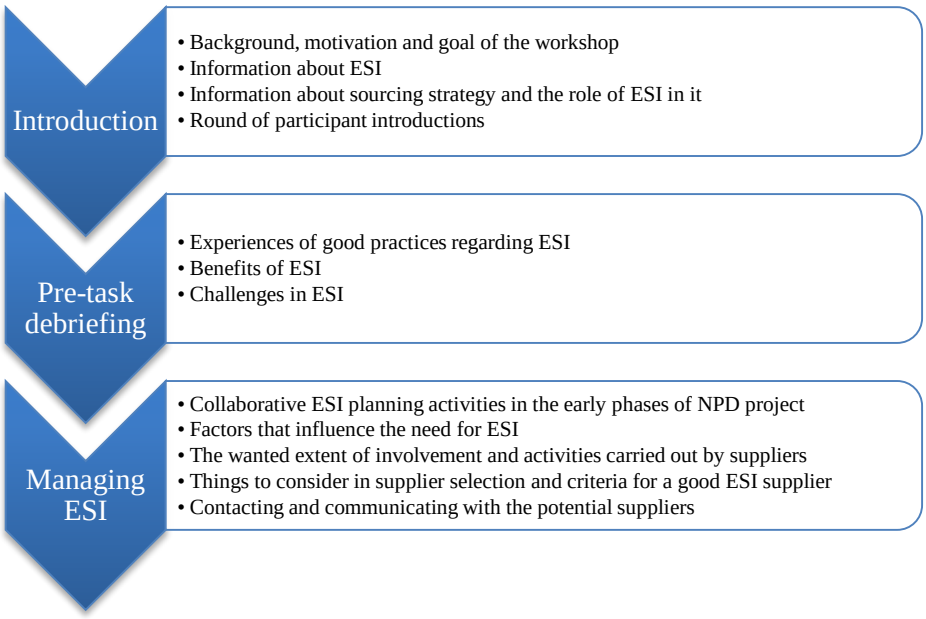


Figure 3.6 *The structure and process of the internal workshops*

Each of the workshops and their tasks were built upon previously collected information. Some refinements were made to the workshop structure in between workshops in order to generate new information every time while still discussing the activities and considerations that need to take place. Due to the broadness of the topic, it was decided that the findings of the previous workshops would be presented to the latter workshops. The first workshop especially focused on the collaborative activities that need to happen within the case company in the early phases of the development process in order to take ESI into account proactively. During workshops two and three a sketch of ESI activities based on the previous workshops and interviews was presented to the participants for commenting and verification. That way improvement ideas, disagreements and agreements would surface faster and the focus could be on the influencing factors that need to be considered in each activity. The participants of the first set of workshops are presented in table 3.1.

Table 3.1 *The participants and durations of each internal workshop*

	Workshop 1	**Workshop 2**	**Workshop 3**
Participants	-R&D project manager -Senior mechanics engineer -Electronics engineer -Sourcing project manager	-R&D project manager -Electronics engineer -Component manager	-R&D project manager -Senior mechanics engineer -Sourcing project manager -Sourcing project manager

	-Component manager		
Duration	2 h 50 min	2 h 30 min	2 h 50 min

In the first two workshops the participants were given more time for individual thinking and documenting their thoughts on post-it notes. The third workshop was recorded and transcribed and less time was given for written documentation during the workshop to facilitate more discussion. In all of the workshops the researcher made notes about the discussion and collected the participants' notes on a poster. The researcher did not actively seek to present his own views to avoid influencing the results of the workshop but he sometimes presented questions for more specification.

3.2.3. Workshops with suppliers

Four strategic suppliers were asked to participate to an ESI day which included workshops regarding ESI practices and communications. The suppliers represented plastics, machining, cables and harnesses and printed circuit board assemblies (PCBAs). List of the participants can be found in appendix 2. All of the suppliers were ones that had already been interviewed. From each supplier 2-3 participants took part in the workshops and the representatives included members of top management, key account management or sales and a technical expert. For each supplier workshop a facilitator was assigned. The researcher facilitated one of the workshops while the other ones were facilitated by three members of the researcher's project team. For each supplier and workshop group employees of the case company were invited to participate. The case company participants were mechanical and electronics engineers, R&D project managers and sourcing project managers so that each group had 4-7 members.

For the workshops a facilitation plan was made so that the facilitators could carry out the workshops in similar fashion. The topics to cover were communication and roles and practices in ESI work. Again helpful questions were drafted to support pondering and discussing these topics. The participants were asked to come up with limitations and suggestions regarding these topics. The topics and helpful questions are presented in figure 3.7.

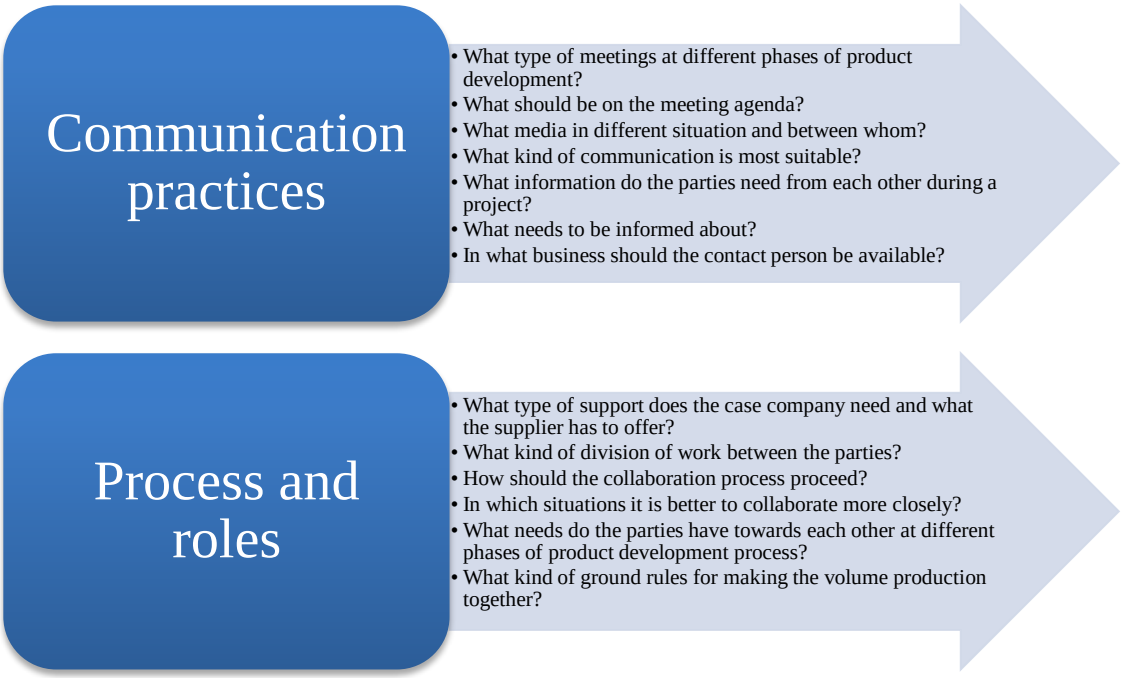


Figure 3.7. *The topics covered in the workshops with suppliers*

The agenda of the workshops were sent to the participants a couple of days before the event. The facilitation plan was similar to the previous workshop as the participants were allowed to generate own ideas regarding suggestions and limitations on the topics, then presenting those ideas and having discussion about the findings. However, the facilitators ended up utilizing different facilitation techniques. The outcomes of the groups were presented with post-it notes and by writing them down on posters which made the documentation about the workshops. At the end of the workshop each facilitator gave a presentation about the key findings of their group's work. Each poster and related post-it notes were later transcribed, categorized and summarized. The workshops lasted an hour and a half with 45 minutes for presenting the results.

3.3. Access to research material

The researcher had access to the research material as an employee of the case company. Access to interviewing the suppliers was arranged through sourcing managers who were responsible for managing the relationship with those suppliers. The workshop invitations were sent by the head of sourcing. The researcher also had access to the case company's intranet pages and other internal forums which offered the researcher better opportunities to seek information and learn about the case company's practices and processes.

Fitting literature was gathered to provide insight on the conditions of the case company and the theories were approached from the case company's viewpoint. Access to the literature was gained through the university's license to well-known scientific portals and e-libraries on the internet. The materials were accepted by the researcher after a

critical review by the researcher based on the publishing channel, amount of citations, year of publishing and contents. The researcher was allowed to participate in two new product development projects to be able to consider and study the practices in real situations. The researcher was also able to study the documented processes of the case company.

4. RESULTS AND DISCUSSION

In this chapter the results of the interviews and workshops are presented. After that the systematic model created to match the case company's need based on the research results and literature review is presented followed by discussion and critical evaluation of the results.

4.1. Results of the semi-structured interviews

In order to create a systematic model to manage ESI at the case company, an understanding about the challenges that the people within the company perceive regarding ESI was needed. Moreover, it is essential to discover the thoughts, improvement ideas and good practices that the employees have about ESI. In the following two sections, the results of the case company and supplier interviews are presented in more detail in narrative form.

4.1.1. Interviews with employees of the case company

The employees of the case company had many direct improvement ideas for ESI practices as well as demands that can be seen as initial criteria for what should be considered in ESI. Several challenges could be recognized as compared to the prerequisites presented in the theory chapter. Moreover, the perceived benefits of ESI were very much in line with literature since many stated that successful ESI may lead to time and cost savings and quality improvements through manufacturability improvements and can also provide a learning system for the designers. It was hoped that the suppliers could provide consultation and an additional resource and support in product development projects to ensure that the parts are of high quality. The key main challenges regarding the internal practices that came up in the interviews are presented in figure 4.1.

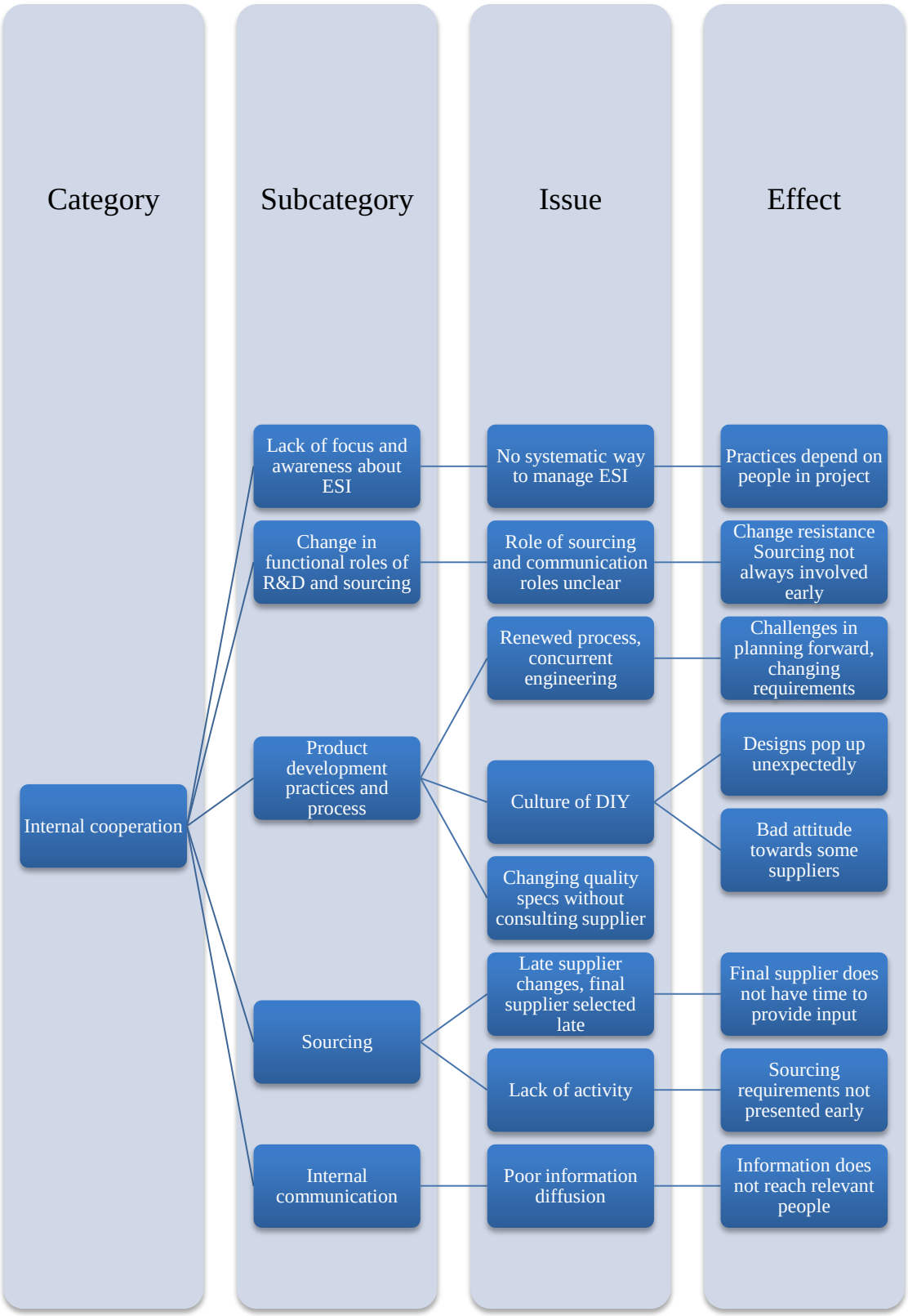


***Figure 4.1**. Perceived main challenges regarding internal practices in managing ESI at the case company according to the interviews*

The interviews revealed that within a couple of years there had been a change in functional roles within new product projects since sourcing has taken responsibility for

negotiating prices, choosing the supplier and ordering the prototypes in projects. Lately there had still occurred confusion about the role of sourcing in new product projects and the project sourcing members sometimes had to give presentations to clarify their role. Change resistance existed among some engineers since previously they were able to select the suppliers and to make orders on their own. The involvement of sourcing in projects may therefore be seen by the engineers as decreased responsibility and as slower and more bureaucratic way of working. The involvement of sourcing has brought other criteria to consideration when deciding which suppliers to use. It was stated that now not only the technology available, speed and price are taken into consideration but the project sourcing team has a better view to sourcing categories who essentially decide which suppliers are potential long term partners for the case company.

Some engineers have interpreted this change in roles in a way that they are no longer allowed to be in direct contact with the suppliers at all. According to the sourcing interviews, this is not what the participation of sourcing means since the engineers are encouraged to be in contact with the suppliers in technical matters and the role of sourcing is to take care of the business aspect to ensure long-term benefits. Sourcing project managers also wish to be kept up to date about the discussions between the engineer and the supplier. Some engineers had bad experiences of independently communicating with the supplier: when forgetting to inform the sourcing manager about the discussion they have been approached in an annoyed manner. However, the interviews gave the picture that the culture had started to change and the engineers mostly consider the involvement of sourcing as positive since it allows them to focus on their core work. More clearance regarding roles was hoped as well as the possibility to remain directly in touch with the supplier in technical matters.

Everyone expressed that currently there is no defined process for involving the supplier early. Many stated that these type of practices are everyday work and that it is often pursued but not systematically. Based on the interviews, it was the common view that the situations where the supplier is currently involved early are related to certain technologies and situations. These cases include especially injection molding where it was seen practically compulsory to involve the supplier early due to the cost and long delivery time of the mold. Also in cases of new technologies or materials being required suppliers have been contacted early to seek information ad-hoc. The process of contacting the supplier has been unsystematic since it was stated to depend on the project and the people within that project whether suppliers' knowhow is utilized. There were several different opinions about who currently carries the most responsibility of contacting the supplier and driving ESI. Most stated that sourcing is in the key role while some stressed the importance of the role of engineers and some mentioned project managers as the driving force. Additionally the practices were stated to vary with different engineer-sourcing combinations. This embodies the fact that there were no systematic way of managing ESI and no clear ownership of it. It was stated that in many

cases the suppliers are approached with finished designs and a prototype order. After prototyping the suppliers are typically tendered and often this leads to changing the supplier.

Based on the interviews, a more systematic approach would be wanted and needed but the most common worry with an ESI process was that if ESI was forced into every situation the engineers and sourcing would soon run out of resources and assumedly the suppliers would not have time for this either. A need was expressed for a systematic approach which would take into account the actual need of supplier involvement, the right amount of supplier involvement and the right timing of supplier involvement. Also it was unclear which suppliers should and could be involved as no one had an explicit idea of the suppliers' capabilities. Also a major question was who should do what and when at the case company's project teams in order to successfully involve the suppliers. It was seen especially challenging that the case company has so many different kinds of products, applications and suppliers but it was stated that especially with the more challenging, totally new products there may be more need to involve suppliers as compared to new versions of old products.

Many interviewees stated that prototypes should be manufactured by the same supplier who also does the volume production. However, there was also a different view since it was stated that if the volume manufacturers make the prototypes they would still use different machinery to manufacture the prototypes and eventually they would have to attempt producing the part for the first time on their high volume machines. Overall in mechanics it was considered that the current situation is rather challenging since many of the volume manufacturers are not able or willing to produce high quality prototypes in tight schedule. It was hoped that the suppliers would take manufacturability into account already in the prototyping phase. As a relevant addition, it was also stated that it is important to distinguish between different types of prototypes when talking about supplier involvement and prototyping: concept prototypes or functional prototypes and prototypes which are already closer to the design of the finished product. The concept and functional prototypes are needed at the very early phases of the development process and they might not have anything to do with the final product design and material and therefore at that time it is not important where to get those prototypes but that they are acquired in the first place and as fast as possible. It was stated that it is not so beneficial to involve the supplier when the requirements and design can still change radically suggesting that the maturity of the design is in a major role regarding the timing of involvement.

Based on the interviews, within product development there exists a culture of "doing it yourself". It was stated that some of the engineers prefer to work on their design on their own and eventually burst out the finished designs. There appeared to be different levels of willingness to discuss the unfinished designs with for example the supplier and in these cases the alternative is to talk about the design with colleagues or trying to

figure out the issues on their own with the help of internet. The old way of doing design work was described as finishing the designs, sending them to the suppliers and then evaluating the supplier's capability based on whether they were able to "make to print" or not. It was stated, however, that this way of doing had diminished but still it would occur sometimes. It was also expressed that the engineers should be more open and active about the phase of their design in order for the other project members to know what is going on.

The interviews revealed that the sourcing project managers are hoped to take a more active role in new product projects especially in the early phase of the project and to actively push their agenda and show their expertise. The suppliers were stated to be typically involved quite late, only after prototypes need to be ordered while there were mixed opinions on the reasons for this. Some engineers thought that sourcing waits for the finished designs on purpose to be able to tender for the lowest price whereas the sourcing representatives stated that often the finished designs pop up unexpectedly without the sourcing managers even knowing that such drawings were under work. Another concern was that the sourcing project managers should have more time for activities other than merely ordering prototypes and doing follow-up on the delivery issues of the prototypes.

Several issues regarding current suppliers and supplier selections also came up in the interviews. These issues are summarized in figure 4.2.

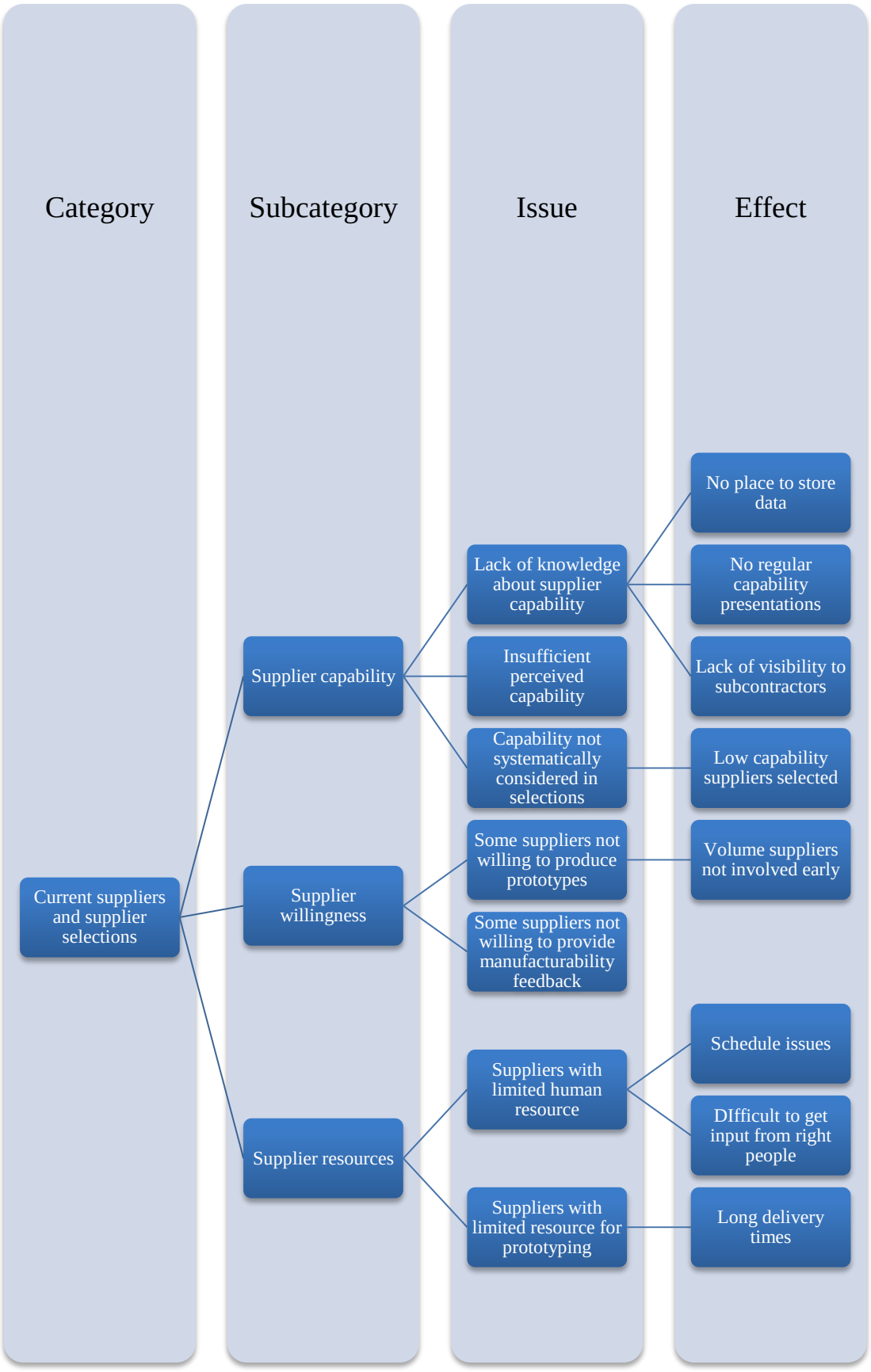


Figure 4.2 *Perceived main challenges regarding current suppliers and supplier selections regarding ESI at the case company according to the interviews*

Capability of the suppliers was considered a critical factor regarding ESI since most interviewees expressed their concerns about this issue. Surprisingly, a frequent concern was the lack of knowledge about the suppliers' capabilities. Particularly the engineers had varying amount of experiences of the case company's current preferred suppliers and some have focused on designing certain types of mechanical parts which have offered them little chance to learn the suppliers' capabilities. Some engineers stated to trust that the sourcing department has a good idea of the suppliers' capabilities and that the ones with required capabilities have been chosen to be preferred suppliers whereas some stated that probably nobody has a clear comprehension of the capability of the supplier network. According to the interviews only quite recently the sourcing department had started to explicitly evaluate the suppliers' technological capabilities on a rather narrow scale and even the sourcing personnel commented that they should have a better idea of the suppliers' capabilities. It appeared that in general the project sourcing team had a poor visibility to these supplier scorecards. This deteriorates the diffusion of supplier capability related information. The sourcing representatives stated that they do not know what kind of support the engineers would want from the suppliers and how well the suppliers could actually support the case company's R&D. Lack of knowledge about the supplier capabilities was also stated to be contributed to complex supply chains and subcontracting since it is not always clear where a supplier subcontracts parts from and which activities it does in-house. It was stated by a sourcing category manager that the case company will seek to more actively define the second tier suppliers for the first tier suppliers in the future. It was also stated that there are no regular meetings or seminars with suppliers where the suppliers present their capabilities. Additionally, it was said that some suppliers might not be confident enough to question the case company's designs due to their high quality in documentation.

Many engineers expressed concerns about the criteria when selecting suppliers for co-operation. Many considered price to be a too powerful criterion in decision making which was stated to have resulted in doing business with some low capability suppliers. The project sourcing interviews revealed that many criteria are taken into account when selecting suppliers. The initial objective is to use a preferred supplier and after that the criteria include for example price, schedule (delivery time), expected volumes relative to supplier's size, quality, past experiences and the level of ability to do manufacturing in-house without subcontracting. The final decision in choosing the supplier is typically done in co-operation with sourcing categories who have the best picture about the suppliers' situations and have the direction of where they want to take those partnerships.

Another critical issue is the suppliers' willingness to commit their input to the case company's new product projects. Many engineers and sourcing managers stated that currently it strongly depends on the supplier whether they provide manufacturability feedback after prototyping or not when asked for it. It appears that some are willing to go through the effort, some suppliers want to get paid for it and some do not deliver.

The case company's high mix – low volume was considered a challenge in providing the capable suppliers the motivation to spend their resources for the case company. Especially regarding prototyping the suppliers' interest seems to vary quite much according to the interviews. Another concern shared by both engineers and sourcing was that many of the case company's current suppliers have very limited human resources. As stated by an engineer: *"the case company's current suppliers don't really have the required resources for ESI activities, the knowhow is bound to a small number of people and they lack internal specialist organizations. Deeper collaboration would require more resources from them".* Therefore even the capable suppliers might not always be able to commit to being involved early due to resources. The suppliers should therefore be able to see the benefits and the potential in being involved early to the case company's NPD.

Some issues that could be categorized to be related to supplier collaboration or supplier relationships also surfaced in the interviews. These issues are summarized in figure 4.3.

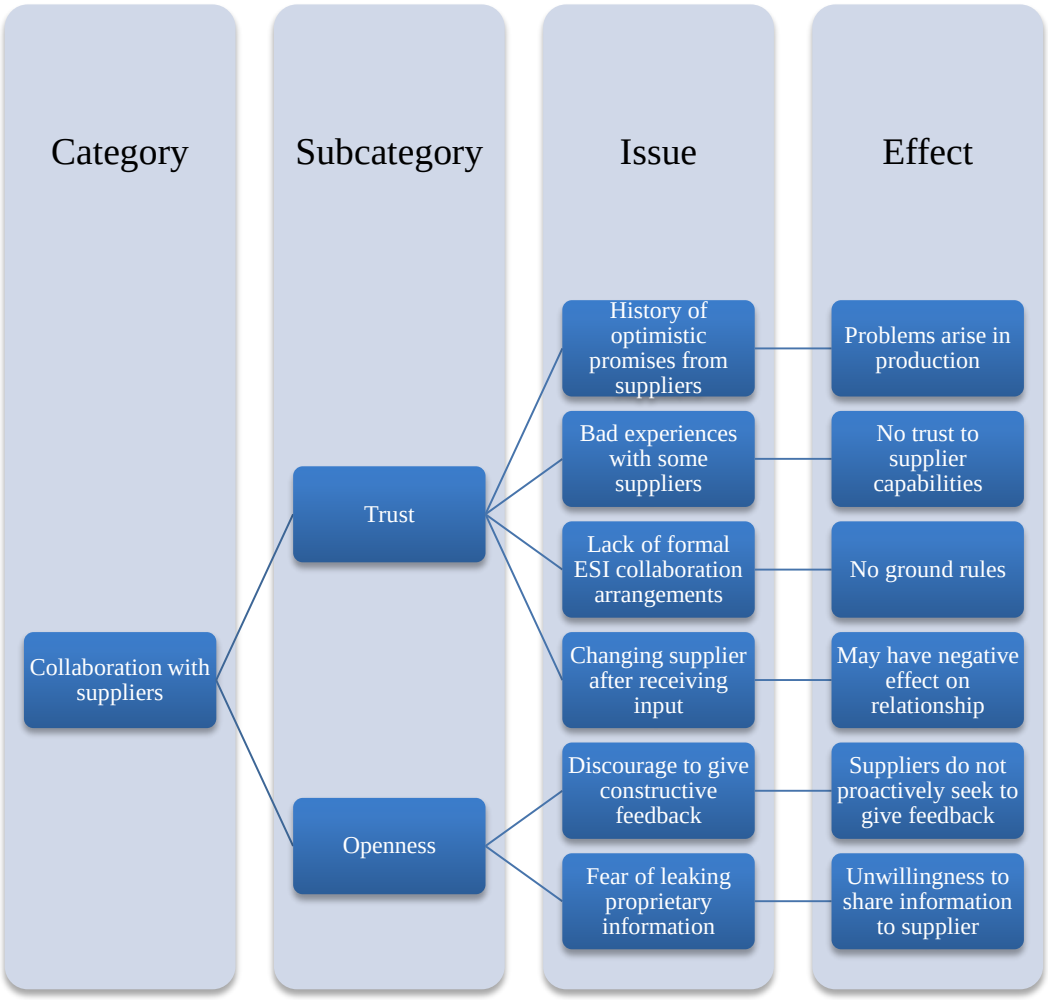


Figure 4.3 *Main perceived challenges in supplier relations regarding ESI at the case company*

The case company was stated to have quite established relationships with the preferred suppliers and that there is plenty of experience in doing business with them. It was stated that the case company should receive support from the preferred suppliers and that it would be easy to involve them since their practices are rather well-known. Especially the engineers expressed their concerns about utilizing the suppliers' capabilities by using their resources and then switching to another supplier after tendering. This was said to increase the contact barrier and to reduce the engineers' willingness to ask advice from the supplier since they may feel that they are taking advantage of the supplier. It was stated by an engineer that "w*e should establish some ground rules with the suppliers. Who are the contacts, which suppliers we can contact in projects and how do we proceed in technical discussions. A contact list would be a good thing, who to contact and in which situation."*

Some concerns arose regarding trust since there was dispute over whether the suppliers can be trusted with confidential information at an early stage of a new product project. Additionally, it was stated that the suppliers should honestly tell if the designs are out of their comfort zone and on the other hand should openly display their expertise.

4.1.2. Interviews with the supplier representatives

The interviewed suppliers showed great interest in the topic of early supplier involvement. All of the suppliers interviewed had good experiences regarding being involved early to some extent and they expressed willingness and suggestions to improve the co-operation during product development with the case company. Only three suppliers out of 11 thought they are usually involved early enough and that they see it alright to continue in a similar manner in terms of timing of involvement. Therefore the common opinion was that there would be room for improvement in ESI practices.

All of the suppliers expressed similar benefits regarding ESI. In addition to manufacturability and quality improvements, time and cost savings, many of them stated that being involved early is a good way for the supplier to demonstrate their knowhow and capabilities and to gain new business. Helping customers was typically seen as part of the supplier's service or sales efforts but it was stated that there naturally is a certain extent to which the supplier is willing to commit their resources without getting paid for it or with high uncertainty of receiving the volume business. Additionally ESI was seen as a way of getting to know each other better and improving the collaboration. All of the suppliers regarded ESI as mutually beneficial for the buying company and for the supplier. Also the perceived challenges were very much similar with all suppliers. The main issue regarding ESI from the suppliers' point of view was resources since all of them thought that being involved early and intensively in every single case would require too much time and effort. Especially companies with small amount of experts saw the lack of human resources as a limiting factor. This is in line

with the interviews at the case company. The key challenges that arose from the suppliers' perspective are summarized in figure 4.4.

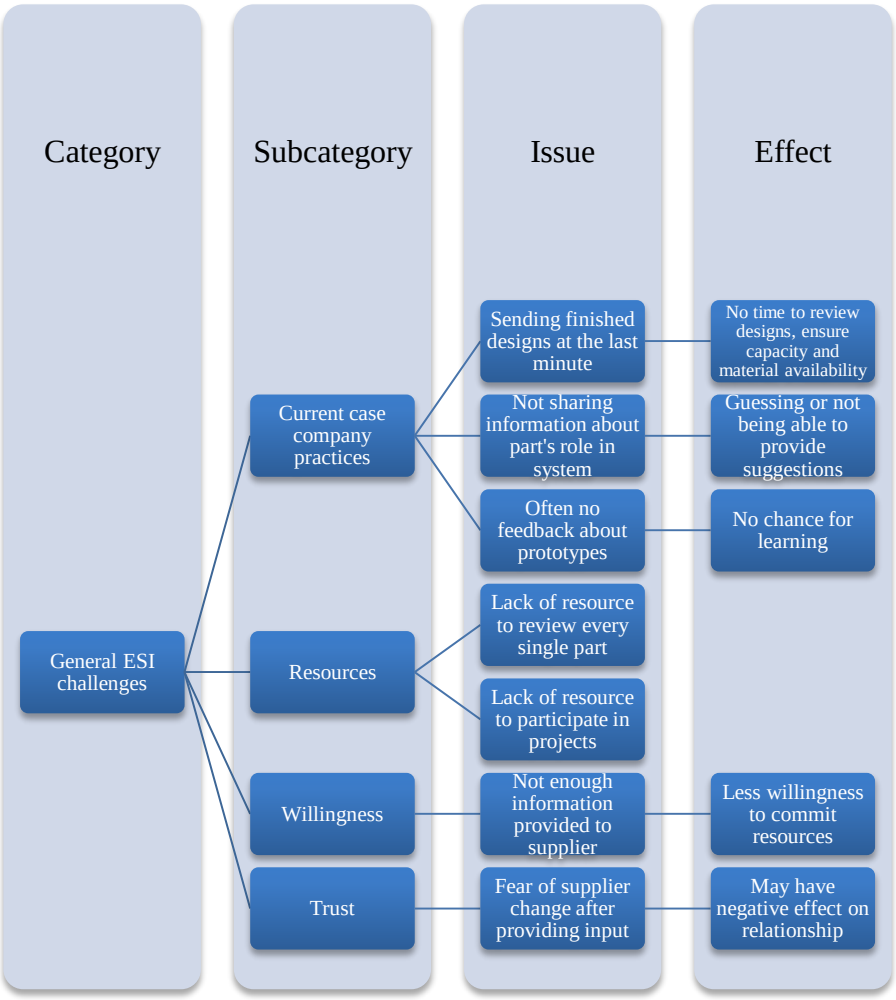


Figure 4.4. *Summary of perceived main ESI related challenges at the suppliers*

It became clear that the suppliers had different levels of resources and capability to participate in new product development projects. None of the pure mechanics suppliers had design personnel of their own but instead they had manufacturability experts and manufacturing process engineers who can provide manufacturability related consultation. With some companies the top management of the company were the same people or person who were also in charge of technical support in manufacturability matters for all customers. Some of the EMS suppliers had a limited amount of design engineers for electronics, mechanics and testing but none had product development of their own. The suppliers seemed honest in admitting if they did not consider themselves as "designers" or "innovators". Therefore the companies also had different levels of willingness to participate in new product projects. Some of the EMS suppliers were willing to join in at the earliest time possible and to represent manufacturing at the table whereas others would prefer to be involved when there are already some concrete plans and drawings. The levels of given input therefore varied from giving manufacturability

feedback and providing consultation in manufacturability to having a seat at the project table as representatives of manufacturing. None of the interviewed suppliers suggested that they would be willing to take responsibility for fully designing parts for the case company. It was stated that the expected volumes and business potential of the new product affect the motivation to provide input as well as the history with the buying company. It was a common concern among the suppliers that after providing a great deal of time and effort to a project the business would anyway go to some other supplier and some of the suppliers had bad experiences of such occasions with some customers. Therefore some arrangement or ground rules regarding this were seen to be in order.

None of the suppliers had systematic practices for being involved in their customer's NPD but many stated to have good and established ESI type of practices with some customers. Through experience some suppliers had learned to better collaborate with their regular customers. While many suppliers already had some ESI experiences with the case company, many suppliers had experiences with other customers where they had been involved earlier and more proactively and they considered that those practices had worked well. One case was mentioned where being involved early was not considered a success due to late design changes from the customer's initiative as it had been decided quite late that the appearance of the product should be different.

The suppliers had very concrete suggestions of how the case company could better facilitate early involvement with them. First of all, the suppliers considered it extremely positive that the case company's engineers are directly in contact in technical matters and they would be willing to help them in manufacturability matters and for example provide information about materials. Especially the machining suppliers stated that it would be good to go through the designs with the customer's engineer since it is often difficult for the supplier to recognize the critical areas in the design. It was seen that when discussing design and technical matters, having middlemen in communication only slows things down and increases the risk of misunderstandings. Moreover, most of the suppliers will not waste resources on questioning the designs in manufacturability sense unless the design is clearly extremely difficult or impossible to manufacture or if it includes very costly or hard to provide materials and features.

A common wish was that the case company would already present preliminary designs or models to the supplier in advance before prototype order so that the supplier could reserve capacity and comment the designs in manufacturing sense. It was stated that often the case company sends finished designs and requests prototypes as fast as possible but then many suppliers seldom have capacity. In order to further improve the manufacturability, the suppliers would prefer assembly models to recognize the critical areas of the design as a part of a system instead of viewing them as single parts and also to discuss the product requirements with the engineers. This is to develop a better understanding of the product. Some suppliers already had these type of practices with their other customers. Face-to-face meetings were generally considered especially

beneficial but particularly the suppliers with more limited human resources thought that they would not have enough resources to tend to the needs of just one customer for whole days but rather some hours a day. In general, the case company hoped to be proactive in contacting the supplier instead of sending last minute rushed orders.

Many of the suppliers considered that some sort of contact matrices would be a good addition since there are many contact persons in the case company and the contact persons vary from project to project. This was in line with the thoughts of the engineers of the case company. Some also wished that there would be clearly defined contact persons to contact every time from the case company so that the people from both companies could get to know each other better and build trust. Kick-off meetings were generally considered a good practice for starting product development collaboration. Additionally many suppliers thought that it would be a good practice to have a debriefing meeting after projects to reflect on how the collaboration went, what was good and what could be improved. The suppliers also hoped for more open communication regarding the case company's needs and the type of support that would benefit the case company. Feedback about prototypes was stated to be appreciated since often the suppliers do not receive feedback about their performance. All of the suppliers agreed that engineer visits from the case company are useful and very welcome since it lowers the engineers' contact barrier and offers the engineers a chance to learn about the supplier's capabilities and machinery and to take that into account in designing.

4.2. Results of the workshops

The workshops were built on the issues left open after the interviews and tackled by discussing the practices cross-functionally within the case company as well as with the supplier representatives. The results are presented in a narrative way in order to demonstrate the flow of discussion. In general, there appeared to be a consensus about what should be taken into account in managing ESI since major controversies did not arise and often the participants stated that the other ones had said what they intended to say. The arguments were often backed up by concrete examples by the participants.

4.2.1. First workshop

The early phases of new product development were first discussed with regard to starting ESI considerations in projects. It was stated that sourcing wants to know about go and no go decisions immediately regarding moving from concept phase to actual development phase, emphasizing the need for early sourcing involvement. About initiating the considerations of supplier involvement the R&D project manager stated: *"we can start charting the need for early supplier involvement already at the concepting phase and it is important that we do this as teamwork"*. It was added that ESI considerations would start with recognizing the requirements and the parts. The R&D project manager stated that *"the engineers have an essential role in determining*

the product parts and communicating the structure towards the project members". The product structure would include commercial parts and parts that need to be designed. It was considered that knowledge within the company can be utilized in charting potential alternative solutions when the parts have been determined on a rough level. These first steps appeared to be commonly agreed upon. Additionally, product inventory cost (PIC) calculations including the combined cost of labor, materials and overhead were considered a good internal practice as part of making decisions about ESI. This was seen to make it possible to design the costs into the product in order to anticipate the costs of the final product.

After recognizing the parts and alternatives it was agreed that the next step would be to proceed towards evaluating the need for ESI on part level. As the sourcing project manager put it: *"we should recognize and evaluate our own capabilities and limitations with regard to the recognized parts and alternative solutions"*. The ideas that came up when considering what should be taken into account when evaluating the need for ESI are presented in figure 4.5.

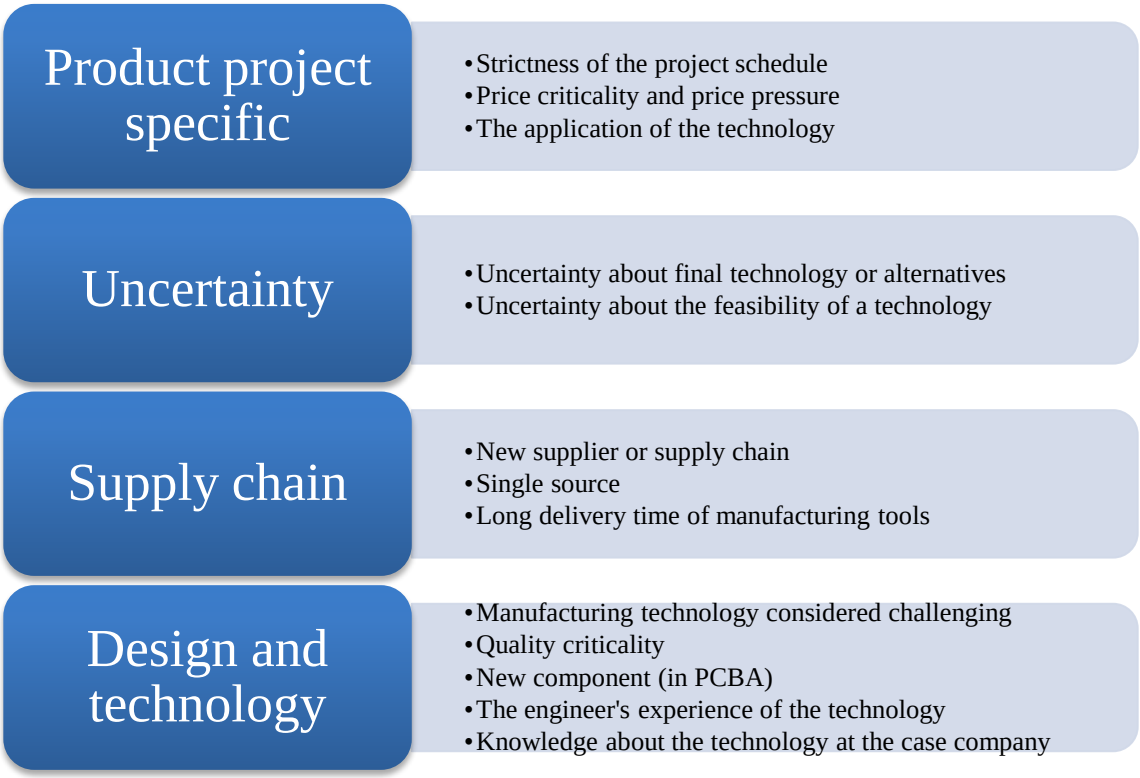


***Figure 4.5**. Factors that influence the need for ESI according to the first workshop*

Talking about specific technologies, the mechanical engineer considered that in mechanics ESI is especially needed when a production tool is needed as it has a long delivery time. Additionally, he considered that supplier involvement is beneficial when there is uncertainty about whether a part can be manufactured by a certain manufacturing technology or how it can be manufactured by it. Regarding the needs in electronics, the electronics engineer considered that the main needs for ESI stem from

new components and new manufacturing technologies or ones that are considered challenging. If new components are needed they might have implications regarding manufacturability. Also dealing with new suppliers – whether they can or know how to manufacture what is wanted – should be discussed at an early phase in order to ensure that a fitting supplier will be selected. In both mechanics and electronics the forms of involvement appear to be related to seeking information and reducing uncertainty as well as seeking for design support regarding manufacturability. However, design related factors do not appear to be the only things that create the need since also supply risks related to quality, schedule and cost are to be considered.

Discussing about the things to consider when selecting a supplier for ESI collaboration the considerations presented in figure 4.6 were stated to be necessary to take into account.

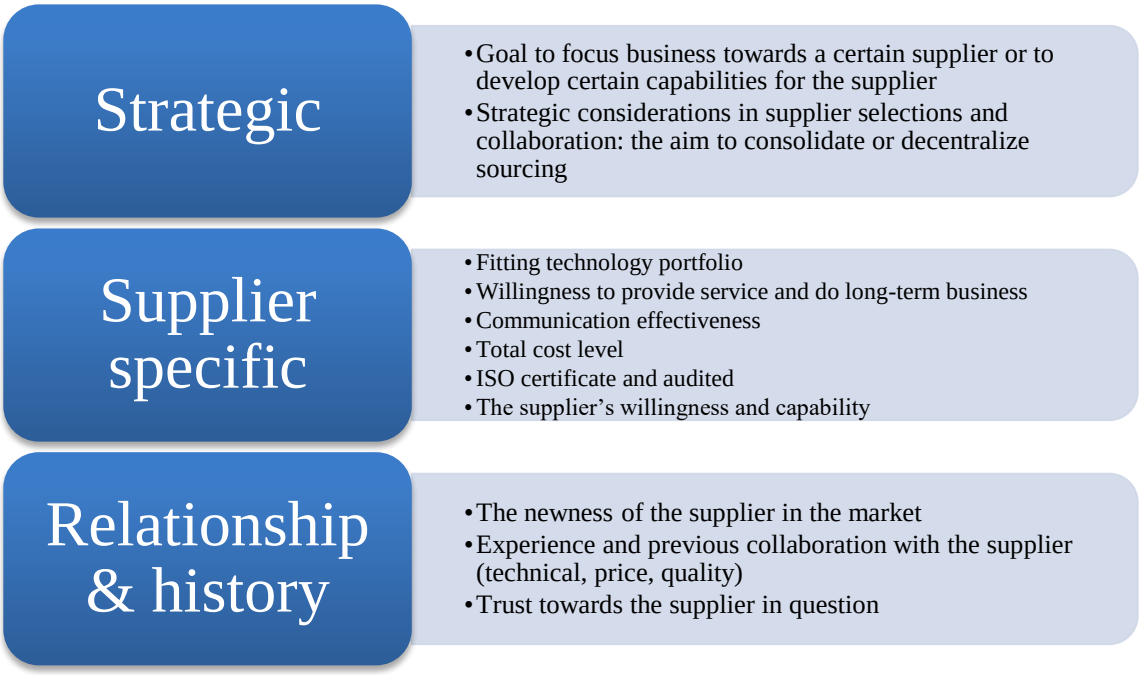


Figure 4.6. *Things to consider in supplier selection according to the first workshop*

Going into more detail about the collaboration and supplier provided input, next the criteria for a good ESI supplier and the tasks they should be able to carry out were discussed. The wanted input and criteria are categorized and presented in figure 4.7.

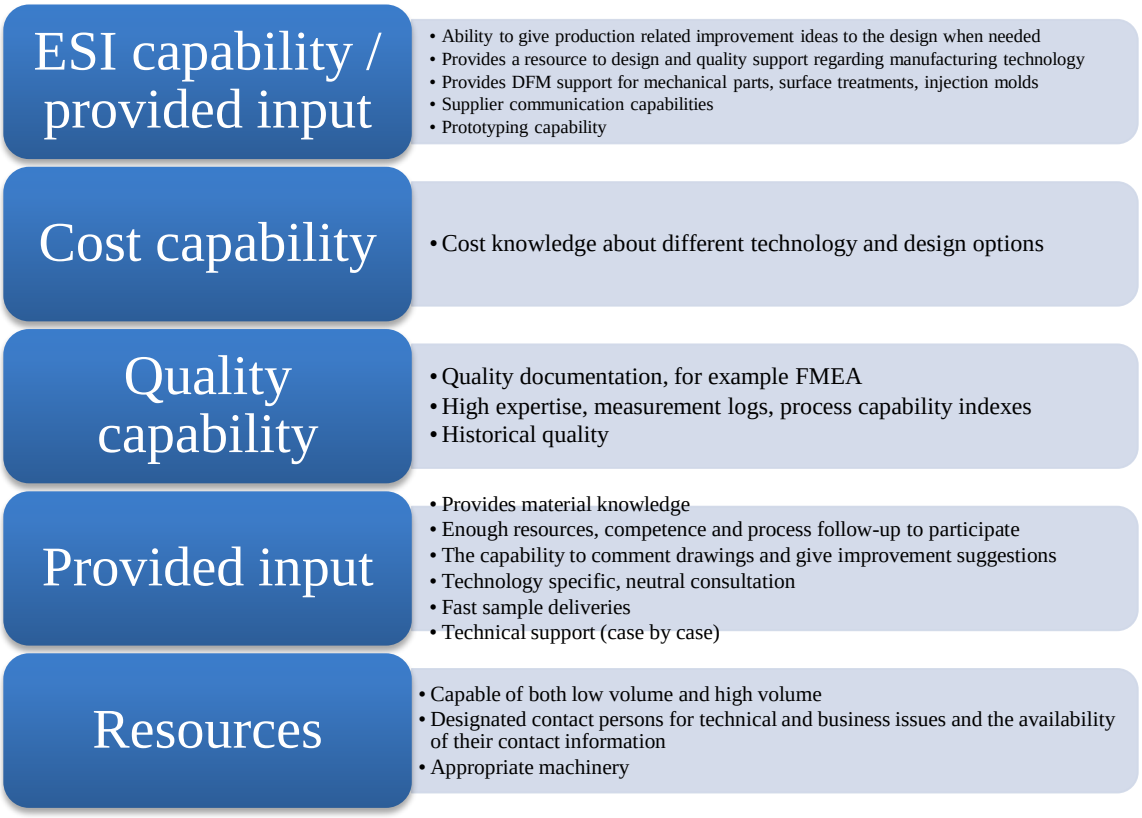


Figure 4.7*. Criteria of a good ESI supplier according to the first workshop*

The next topic of discussion was communicating with the potential supplier(s) when looking to seek input from them. It was stated by the R&D project manager that "*the potential suppliers should be agreed upon together at an early phase as in which suppliers will be contacted"*. It was considered that it is here that clear ground rules should be set by communicating openly and truthfully about the case company's intentions. It was stated that the suppliers should be given as correct and detailed idea about the project as possible and the component manager added that *"the amount of information given depends on the case and the supplier and with our key suppliers we should be able to share information openly"*. However, non-disclosure agreements (NDA) were found to be necessary in any case when sharing more information about projects. It was stated that contacting the supplier should not be a heavy process with lots of bureaucracy but instead the engineers should communicate with the suppliers in technical matters while sourcing is responsible for communicating the business case to motivate the supplier. It was stated by the sourcing representatives that sourcing should be kept aware of the communication with the supplier. For the engineers to have direct contact with the suppliers they should be able to provide connections to their technical experts.

In order to motivate the supplier it was stated that right from the very beginning the case company should start building a win-win situation between itself and the supplier. Honesty and openness from the case company's side was considered important: *"the*

supplier should be informed in the very beginning whether it's about just prototyping or if there is a chance of volume production as well". The suppliers should for example be given information regarding the expected volumes, life-cycle of the product, prototype and volume schedules and batch sizes. It was stated that *"communication and trust are essential regarding ESI and they directly affect how well the collaboration works"*.

Regarding the importance of prototyping with the final volume supplier it was stated that typically there are several rounds of prototyping and during this time the supplier can commit to the project, learn and build production capability. This emphasizes the importance of finding and involving the final volume supplier at an early phase as well as the prototyping capability of the volume supplier. It was stated that by discussing with the suppliers in early phases of product development project the intention is to seek the best option and the best result. It was seen that the final supplier should be the one that is best with regard to price, quality and schedule evaluations and evaluating this early is key. It was suggested that suppliers could be pre-selected for product development projects. There was a consensus that the suppliers should be rewarded from their input with projects instead of just 'sucking information' out of them and regarding this it should be communicated to the suppliers why the case company decided not to continue to volume production with them if supplier is changed.

In electronics it was stated that an already established and a good practice is to send preliminary list of the bill of materials (BOM) to the supplier so that they can check the availability and procure the components well in advance. Additionally it was stated that receiving manufacturability feedback is a great practice but it was added that it may be no use if the production is then transferred to Malaysia after practicing with some other supplier.

4.2.2. Second workshop

In the second workshop, the results of activities from the first workshop were introduced to the participants as a preliminary model with activities. The model initially mainly received accepting comments and the R&D project manager stated: *"this is a good outline of how it should go"*. It was agreed that it all begins with the requirements and that first a draft of the product structure is needed. About the importance of cross-functional ESI planning and early sourcing involvement the electronic engineer stated: *"one time we had an engineer driven project and due to the lack of sourcing resource in the project we could not chart solution and supplier alternatives and therefore were not able to determine the solution"*. It was added by the project manager that the project results have been better with sourcing involved. Regarding alternative solutions it was again mentioned that there should be plenty of knowledge in-house and this knowledge should be utilized.

As an addition to the model presented, the R&D project manager stated that considerations whether to outsource development of parts could also take place or be related to planning ESI activities. This is due to the fact that sometimes but rather rarely in projects some part designs are outsourced. It was seen that the sourcing representatives in projects would be the responsible for making sure that ESI will be taken into account in projects whereas determining the product structure and alternative solutions is mainly the responsibility of engineers. The whole concept of ESI and related activities was seen to require collaboration within the project. It was stated that when charting potential suppliers it is possible that there is a need for a completely new supplier for a new technology.

Another addition and an already used practice by the R&D project manager was proposed to the model. That is, before contacting any suppliers it should be agreed within the project who discusses with the suppliers and about what, which suppliers will be contacted and what information can be shared considering the potentially proprietary nature of the product and the trust towards the suppliers. It was considered important to honestly tell the supplier whether there is a chance to gain the volume production or if prototypes are the only thing needed from that supplier. Things to inform the supplier about could include for example the requirements, target price and application of the product. It was stated that it should be ensured that the supplier understands the product and that NDAs are in effect. When contacting the supplier and seeking their commitment and input, it was stated that the case should be “sold” to the suppliers for example by explaining that the business case could be won by presenting their knowledge and capabilities in product development support. Dialogue with the suppliers and the means to motivate them was considered essential and there should be more efforts to communicate the case company’s needs to the suppliers. It was considered to be especially important to get things right in bigger volume products.

Criteria for a good ESI supplier according to the second workshop are presented in figure 4.8.

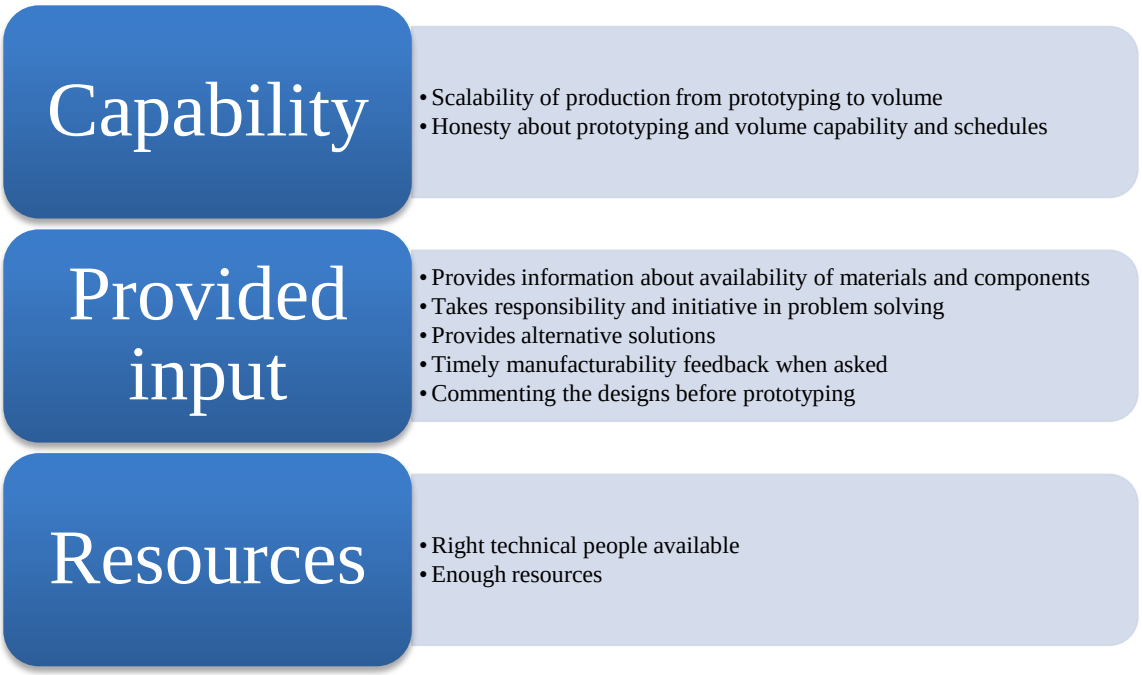


Figure 4.8. *Criteria for a good ESI supplier according to the second workshop*

Considering the design collaboration with the suppliers, it was stated that decisions and actions should be documented and especially if something is agreed over the phone. It was stated that options should be kept open in terms of design solutions to avoid getting locked in to a certain solution at an early phase. This tells about the uncertainty that takes place in the early technical concept phase of the development and the challenge there is to coming to a decision about the most fitting solution and consequently the most fitting supplier. It was considered essential that the supplier has enough resources available and that IPR issues would be taken into account if giving more design responsibility for the suppliers.

Collaboration with the suppliers in different phases of NPD was next discussed by presenting the participants the activities in each phase. It became clear that the activities wanted from supplier are rather well connected to the activities described in the product development process of the case company implying that possible wanted inputs from the suppliers in each phase would be to support in these internal design activities. Discussing about involving suppliers at the technical concept phase it was stated that a lot of time is spent at the case company in thinking how some technical issue could be solved and there the suppliers' input could be beneficial. The electronics engineer stated that generally things work in electronics as they are now. Typically the supplier is selected and involved after the unit has been designed and components selected and it has not been seen as important to involve the supplier earlier. It was added that when involving the supplier early the supplier's collaboration capabilities can be evaluated at an early phase, finding the best partner. It was stated that especially one cable supplier has learned to understand the special requirements of the case company and that they take it into account in their production.

Next the activities in detailed design phase were discussed. A good practice regarding this phase was suggested to be going through the production process with the supplier to learn about the effects of design decisions on the flow of production. It was stated that the old product development process included visiting the supplier at every design review which was a rather heavy procedure but on the other hand that way people got to know each other and open issues were solved at the same time. It was stated that in mechanics, supplier expertise of surface treatments and related critical issues would be beneficial at this point. In prototyping and testing phase where the design is already rather mature the main collaboration activities were stated to be manufacturability feedback and initial preparations for production as well as arranging production testing.

It was finally stated that it is curious why the collaboration does not appear to work with some suppliers: when a certain supplier uses subcontracting to manufacture prototypes for the case company the surface treatments are not as ordered and the delivery times are extremely long resulting in not receiving proper prototypes in time. Therefore it should be known whether the supplier uses subcontracting for prototype production.

4.2.3. Third workshop

Again in the third workshop, the refined model from the previous workshops was presented to the participants. The mechanics engineer stated that it has too many steps since the products in his business area are often so straightforward in terms of material and manufacturing technology selections whereas the products in the other business area typically have more open issues and uncertainty. However, the project manager and sourcing manager stated that this type of systematic approach is a good way to make sure that the things have been taken into account and considered in both business areas. It was also seen as a way to challenge to consider the influencing factors to help in selecting the fitting approach towards the suppliers in each project. It was generally considered a good thing that evaluating the need for ESI was included. Another statement was that recognizing potential suppliers already takes place at the same time with determining product structures and technologies included since the company aims at using its known preferred suppliers. This also implies that in practice it may be difficult to put the activities in linear order and that the separate activities may happen in a very short period of time.

Regarding the implementation of the model, it was suggested that it should be integrated in existing processes as it includes many steps that are part of various processes. It was again stated that it is mainly the responsibility of sourcing to promote ESI in projects and to drive project members to consider it together and again the preparations for ESI activities were seen as a joint effort. The R&D project manager stated that sourcing should know how to manage ESI i.e. knowing the steps in the model and then it is also easier for the project manager to say who should discuss with whom. The mechanics engineer stated that recognizing the need for ESI in design support sense is the

responsibility for the engineer followed by an addition from a sourcing manager that it then requires honesty from the engineers and the project team in admitting that supplier input might be beneficial. Also the expertise of sourcing was put on the table by the other sourcing project manager: whether sourcing has the knowledge to be able to provide alternative solutions is key and it requires technical knowledge. Additionally, the sourcing project manager had an improvement suggestion: *"as a part of this we must also consult with our sourcing categories, they may have strategic needs to direct our sourcing to a certain supplier and this we must take into account".* It was also again stated that the suppliers are not the only source of information regarding solutions since existing solutions within the company should be sought, replicated and used.

Regarding the needs to involve the supplier it was stated that often there might be only one critical issue in the project that needs to be solved while detecting the critical issue may not be easy. The mechanics engineer put it in words: *"in every project there is a need for some amount of communication with the supplier but when and how deep collaboration, that's the question".* Discussing the influencing factors the following were stated:

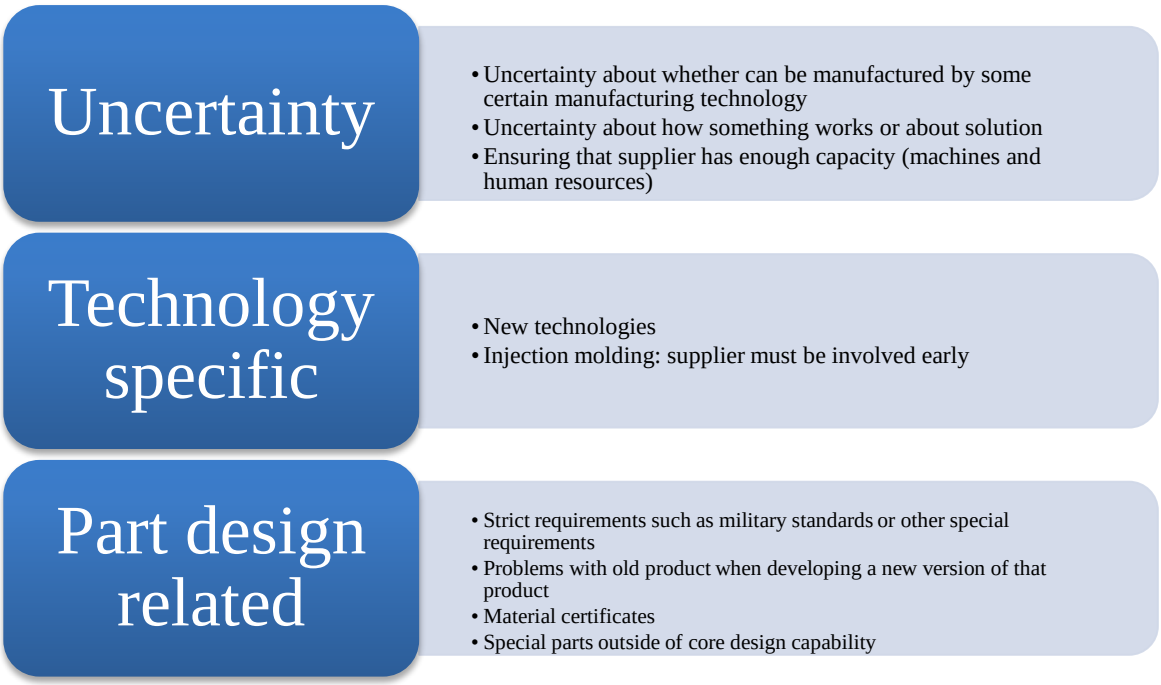


Figure 4.9. *Factors that influence the need for involvement according to the third workshop*

Engaging the potential suppliers was discussed next. It was stated that by open and honest communication taking advantage of the supplier can be avoided. Clear ground rules on whether to pay for help, if the goal is to give the volume production to that supplier and if tendering will happen anyway should be made clear so that the actions and decisions by the case company should not come to the suppliers as a surprise. Schedule and volume information should be given to the supplier about prototyping and

ramp-up. The case company's view about the critical issues in the parts and products should also be communicated. It was stated that the supplier relationship should be such that information can be shared openly and the more open the communication the better service suppliers provide. Therefore the suppliers should be provided information about the product and where it is going at the end customer. Sharing information was seen more risky with new suppliers. The wanted supplier responses were also discussed. It was stated that the suppliers should provide honest answers on whether they can help or not and whether they can match the schedule needs especially in prototyping phase since delivery delays and quality issues slow down the project. Contact information and honest price estimates were also as important information from the supplier.

The practice of target costing, communicating the target costs to the supplier and supplier pricing behavior were also discussed. Sharing target costs with supplier was considered rather risky and it was stated that first clear policies about this type of practice should be agreed upon in the case company and the targets should be realistic and possible to reach. It became evident that there is some mistrust towards supplier pricing practices regarding changes in design. It was stated that the price does not decrease according to manufacturability improvements but instead goes up when more details are presented. The R&D participants stated that price always increases and that it sometimes seems as an excuse to raise the prices when designs become more complete while the other sourcing project manager stated that prices may also go down when manufacturability is improved. It was added by the sourcing project manager that here sourcing negotiation skills come into play.

When discussing about the final volume supplier selection regarding ESI, it was stated that *"the final supplier should be one that is most fitting in terms of price, quality and schedule evaluation"* but that *"it depends on the project and part which one of these is priority".* Additionally, the supplier should have competitive pricing, capability, resources and should be a trusted supplier. It was suggested that the selection should be made according to established criteria which are the same towards all suppliers. This would require deciding what is actually wanted from the suppliers, the measurement parameters for it and a way to extract this information from the suppliers. The criteria should be the same to all suppliers. It was also stated that suppliers could sometimes be pre-selected for involvement in new product development based on knowledge about their capability and agreements on category sourcing level as well as fit for the project.

The parameters that could be measured to evaluate the suppliers' ESI capability were then discussed.

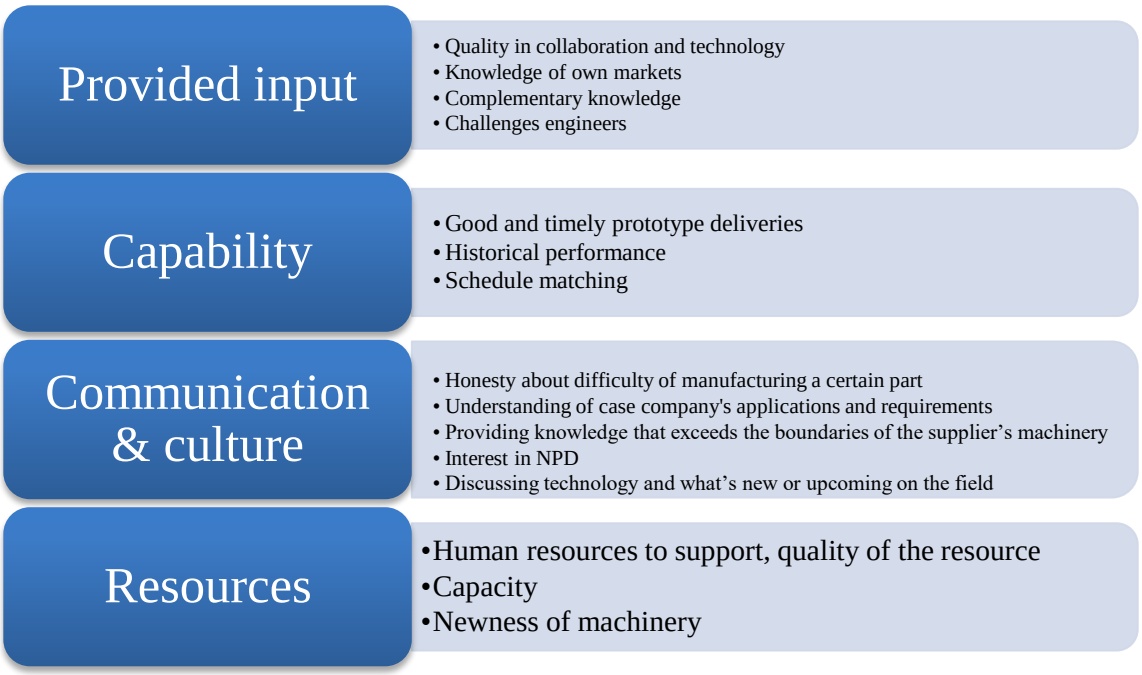


Figure 4.10. *Criteria for a good ESI supplier according to the third workshop*

Another criteria for evaluating a good ESI supplier was stated to be good and timely prototype deliveries. It was also stated that the suppliers should understand the nature of product development: uncertainty and the need for flexibility to changes. It was stated that some suppliers have understood this and do not charge for all changes in the design since changes in design are expected. It was added that the supplier should have sufficient resources and possibility to connect their technical experts to the case company's. Additionally it was stated that the suppliers should have the motivation to take ownership of the project.

When discussing about verifying the benefits of ESI in projects, it was stated that the benefits are very difficult to verify after the project since there are many variables. The contentment of the project group was seen as one way of verifying this – if the project is satisfied with the collaboration and the results then ESI has been beneficial. Additionally correlation between utilizing ESI practices and the realized product quality and costs with regard to related goals could be assessed.

4.2.4. Summary of supplier workshops

Although the suppliers represented different technologies there were clear commonalities in the results of all workshops. The main differences could be attributed to focusing on technology specific critical aspects that should be addressed in ESI collaboration.

In the workshops it was commonly agreed that a more systematic approach to ESI is needed and the workshops pretty much verified what the interviews and previous

workshops had suggested. The general opinion was that communication and collaboration should be based on openness and honesty and that there is a mutual willingness to co-operate at an early phase of NPD. The principle of ESI should be to aim for volume production together while improving quality and manufacturability, selecting the right materials and components, being aware of schedules and sharing information in the process. In one workshop it was suggested that setting target costs and reaching them might be a suitable method to determine whether to continue to volume production together. Regarding plastics and machining which can occasionally be competing technologies it was stated that it is understandable if the case company decides to change to a supplier of different manufacturing technology based on the customer need. The collaboration should begin with a kick-off meeting where the case company should provide information about the project and product. The suppliers need information about the project schedule and objectives, product functionality and requirements, expected volumes and expectations regarding the collaboration. The case company especially needs information about prices, suppliers' schedules, capacity, materials, possibilities and limitations. In the kick-off meeting the project's follow up practices should be agreed on. The critical features of the product should be reviewed and evaluated together and closer collaboration and communication should be practiced when deemed necessary. There were differences between different technologies in the critical things to take into account.

Also contact information of the people involved in the project should be exchanged between the companies. Also contact information to relevant other suppliers for that product should be provided to the supplier so that the suppliers can co-operate in the project if needed. In general it was stated that there should be more collaboration among the involved suppliers in projects. It was the common view that there should be a proactive grip on prototyping: sending preliminary designs and having the supplier review the designs before prototype manufacturing. The project follow-up would include status updates of the project, reviewing the maturity of the design, schedule and price information becoming clearer, prototyping schedules and giving feedback about designs and performance. It was agreed that manufacturability feedback should flow from the supplier to the case company and back to the supplier. At the end of the project a lessons learned meeting should be arranged to reflect on the collaboration.

4.3. Taking the influencing factors into account: A systematic model for managing ESI in NPD

4.3.1. Starting point for ESI practices at the case company

Based on the research the starting point for the case company was not optimal for ESI when compared to the prerequisites, barriers and success factors presented in the theoretical section. At the beginning of the research the case company did not have a sourcing strategy and ESI was not a topic of focus. It can be stated that the strategic

alignment on the strategic and operational levels was not optimally aligned for ESI. Initially the case company did not have technology roadmaps and systematic target costing and cost follow-up practice. Supply base reduction was already in practice but the case company did not have defined strategic partners. Supplier selections and development efforts were not focused on product development collaboration capabilities. However, many things at the starting point were already supportive of ESI.

Many of the case company's main suppliers are within driving distance and there appeared to be quite good and established relationships with some preferred suppliers and good experiences of working with them. Moreover, the company's sourcing organization had a fitting structure for managing both the strategic and operational arenas. The case company had made the separation between operational purchasing and strategic sourcing, employed component experts that operate in the interface of sourcing and engineers and had sourcing representatives participating in product development projects suggesting that the organizational structures were be rather supportive of ESI activities. The case company already followed a concurrent engineering process that was explicitly defined although the process was quite recently renewed and the gates were not as definite as they were before.

The sourcing strategy introduced at the case company initiated a set of changes to better support ESI practices by improving on several of the previously mentioned areas. It can be stated that ESI received top management support and commitment through the sourcing strategy. Cross-functional collaboration was improved on several levels. The role of this study was to provide help for managing ESI in practice. The next sections provide the information and guidelines that should be taken into account at the case company in managing ESI.

4.3.2. Organizational factors

Case company specific organizational characteristics regarding managing ESI were identified based on the interviews, workshops, participatory action research and informal discussions and they are presented in figure 4.11.

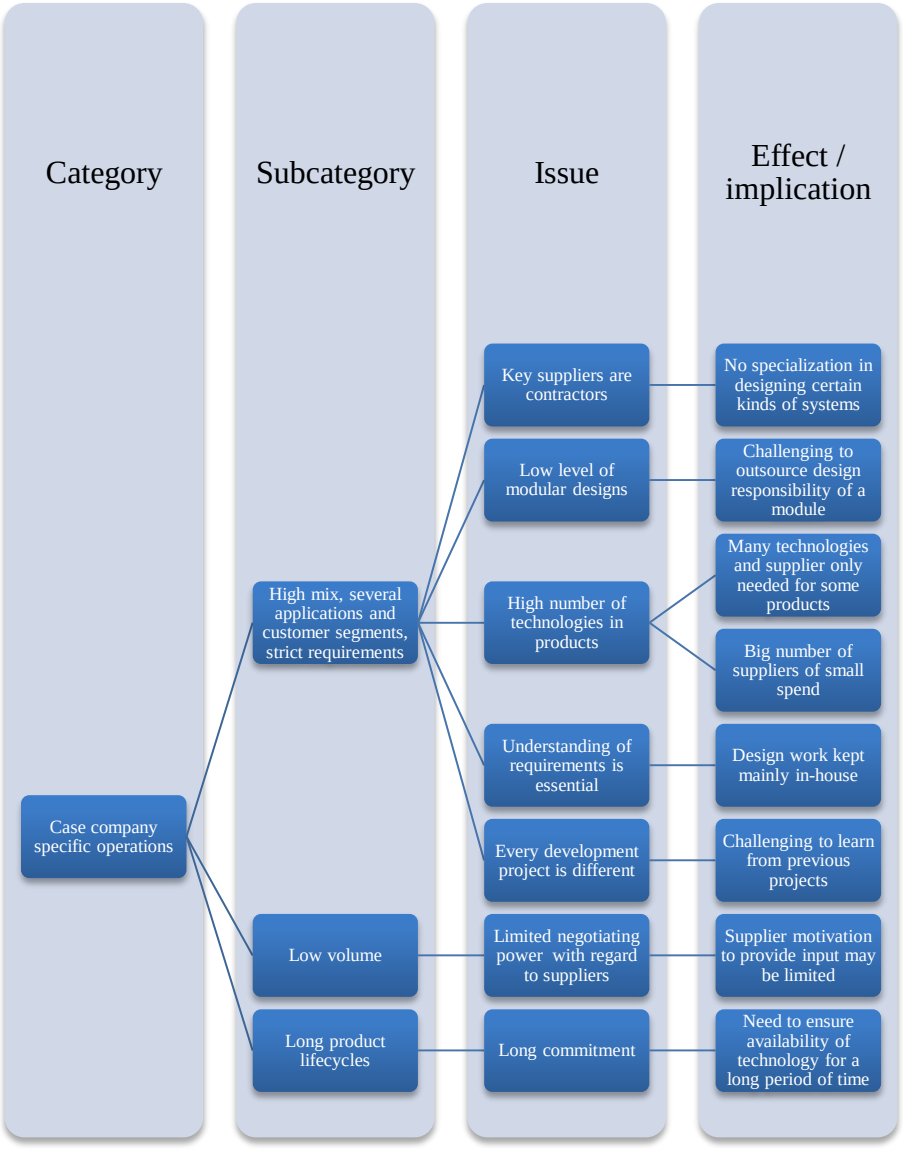


Figure 4.11 *Organization specific factors that influence ESI considerations at the case company*

Due to low volumes it may be challenging to motivate the suppliers to provide input to the case company's NPD. High mix production model has several implications regarding. Majority of the case company's main suppliers are contractors who are not specialized in serving the needs of some certain industry and are not specialized in design work. There is a huge variety of different technologies in the case company's products and consequently there is a high number of suppliers whose technologies are only required for certain products. The case company's products do not systematically include modules for which a certain specialized supplier could take design responsibility and on the other hand majority of the design work is wanted to be kept in-house since the designs are considered to be of core competence. The case company's long product lifecycles imply that the availability of the technology should be ensured years ahead. The organizational factors can be seen as the causes for the variance and guide decision making on the project level.

4.3.3. Taking the influencing factors into account in managing ESI: the systematic model

As compared to the influencing factors presented in the end of the theoretical part, the research suggests that the case company has several distinct features that need to be taken into account in the management model. The high mix of products and product applications and market segments results in a vast amount of variation in the projects in terms of uncertainty, complexity, type of new product, critical features in part designs, architecture, volumes and technologies included. Accordingly, there may occur needs to look for new suppliers during the project due to specific technology.

These factors should be taken into account in each project and for each part and the suitable approach to involve suppliers and coordinate the collaboration should be chosen accordingly. Therefore it can be stated that there is not one way of managing ESI at the case company since the decisions need to be made in the projects. However, what can be made systematic is taking the influencing factors into account by providing instructions, steps and a mindset for managing ESI which the ESI model presents on a general enough level to provide insight to any project.

During the research process it was decided that driving and facilitating ESI is the responsibility of the sourcing project managers that participate in the development projects whereas strategic sourcing managers are responsible for supplier development also in ESI capability sense. Although project sourcing is responsible for managing and facilitating ESI, it calls for the input of several stakeholders to make the model work in practice. The model aims at making decisions regarding a single designed part or assembly manufactured by a certain supplier.

The model consists of the key steps and closely related activities that are beneficial to consider regarding ESI. The essential related activities (cost management and requirements engineering) continue throughout the process. Although the model is presented as a linear process it is expected that some activities may happen in parallel and in an iterative fashion. The model and ESI considerations begin with internal cross-functional collaboration to prepare for and plan ESI and engaging the suppliers to receive information and reducing options. This can be seen as a continuous process throughout a product development process until the supplier has been selected. The ESI model is presented in figure 4.12 and the steps and things to consider are presented in more detail below.

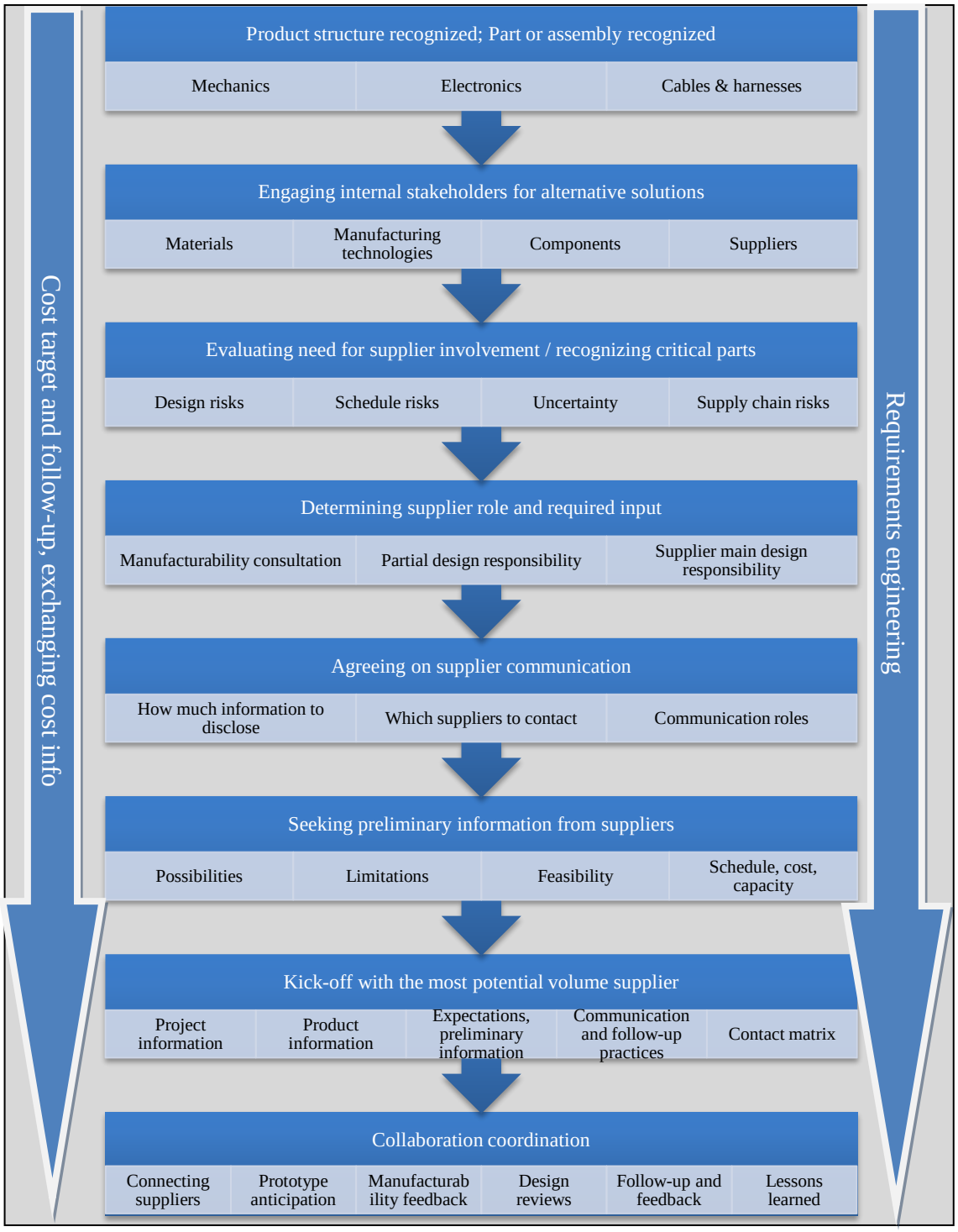


Figure 4.12. *A systematic model for ESI in NPD*

Project characteristics as a starting point

When entering a new product development project one should understand and make conclusions about the type of product in development as it has implications regarding ESI. Sourcing should be involved in the development project from the very beginning since also ESI considerations can begin already at the technical concept phase with cross-functional collaboration. The initial things to consider include the project's

schedule, resources and the type of product developed as a result of the project in question. Resources as in project team composition is an important aspect in concurrent engineering since lack of certain resource may delay development work and on the other hand late involvement of internal resources may similarly cause design changes. With fundamentally new and more complex products there most likely is more uncertainty involved in the project with regard to technology and supplier selections. With more complex product projects there is likely to be more technologies and suppliers involved which may force to prioritize involvement efforts due to resources. Regarding new versions of existing products the suppliers of the previous version's parts may have good expertise and insight regarding the product and its manufacturability and this insight should be utilized. Fundamentally new products are more likely to be more proprietary by nature which may limit the amount of information to be shared outside of the house.

Related continuous process: requirements engineering

Requirements engineering is an ongoing key process that should be understood also with regard to ESI. Basically, the defined requirements determine whether the project itself knows what it wants to develop and what features need to be included in the product. The matureness of requirement definitions is an important determinant on when the project is mature enough to start considering ESI with regard to involving the most potential volume supplier. Especially strict requirements and possibilities for including new technologies can sometimes already be seen at the concept phase based on requirements engineering. For example military standards or totally new functionalities may indicate that new technologies and consequently new suppliers will be required or that especially close collaboration will be needed to ensure meeting the strict requirements. Understanding the requirements and maturity of the development project requires constant evaluation and interaction within the project team. Requirements stem from for example customers, regulatory officials, competing products in the market, issues found with previous versions of the product and internal stakeholders who participate in the development project.

Related continuous process: target cost and cost follow-up

Understanding the product's material and labor costs is an essential part of product development. Continuous cost follow-up and seeking cost information from suppliers are important processes that support ESI activities. Having a cost target and doing follow-up on the costs helps in avoiding ending up with a too expensive product and on the other hand cost understanding and cost discussions with supplier offer an improved chance of ending up with a price that was anticipated and is accepted by both parties. It is important to have price discussions with suppliers and gather preliminary cost information throughout the process.

In order to have targets to strive towards and potentially communicate to the suppliers as well, operational targets should be set regarding schedule and cost. Again, some projects are more uncertain and complex than others and therefore predicting the costs may be more challenging with some projects. Also, some projects are more cost driven than others due to higher competition in some product areas. BOM target cost or cost estimation practice should be utilized especially in the case of price critical products in order match and ensure that the individual parts and products do not end up too expensive in terms of material costs. The proper use of BOM target costing requires the product to have a target price and target profit margin which so far has not been the case in many projects. There are also other methods of receiving reference costs: similar parts in other products or in previous product version or request for quotations (RFQs) to find out a reference market price. Even in the absence of a specific cost target, BOM cost follow-up should be carried out throughout the project.

Product structure recognized

As the development projects are highly different from each other it needs to first be recognized what kind of building blocks the product will comprise of. It would be rather simple to systematically determine which structures require certain level of supplier involvement if the case company only developed and manufactured single types of products with a dominant design (design that is considered industry standard). The product structure and the parts, modules and assemblies that the product includes becomes increasingly clearer as the process progresses. Only when there is an idea of the product structure or at least some individual parts it can be determined what kind of technologies and suppliers more specifically might come into question to meet the requirements and implement needed functionalities. Still there might be several options for the determined structures and these options should therefore be addressed. When there is an idea of the product structure and related parts and assemblies it needs to be determined which parts will be designed and which ones will utilize commercial or existing solutions. Recognizing the product architecture, assemblies and parts within the architecture is needed to determine the type of parts and technologies that the product will include.

Engaging people within the company for alternative solutions and suppliers

When seeking alternative solutions for individual parts, one should first engage people within the company and promote standardization and commonality by utilizing commercial components and existing solutions as this is prioritized at the case company. Especially with PCBAs one can look for previously used solutions in order to replicate and tailor it for the current needs. Especially engineers, component managers and other technology experts have knowledge about components, materials and manufacturing technologies. If the requirements are clear and the project is rather

straight-forward new version of an old product, there may be less need to seek for alternatives for a certain part.

The case company's products comprise of different types of parts which require a different approach and therefore it needs to be understood which parts should be reviewed in terms of ESI. Decisions need to be made regarding whether to select a part from a commercial catalogue, to design a part or to utilize an existing solution. If commercial or existing solutions cannot be utilized, unique designs are needed. These items comprise of mechanical parts, electronics, and customer specific cables and they should be reviewed in terms of need for ESI. With all options it should be ensured that the availability of the technology matches the lifetime of the product. A typology was created to distinguish between different parts and it is presented in table 4.1.

Table 4.1. *Parts typology*

- Simple commercial off-the-shelf components
- Complex commercial off-the-shelf: potentially tailored for the case company's needs
- Designed parts
    - Mechanics: generics (machining, sheet metal, injection molding, castings) & special modules and assemblies
    - Electronics: PCBA & LTCC (low temperature co-fired ceramic)
    - Customer specific cables

Interaction with suppliers of commercial solutions may also be needed at early phases of development but actual product development collaboration comes into question with designed parts or assemblies which ESI in this study deals with. Internal stakeholders should be engaged regarding potential suppliers of the potential technologies for the unique parts. According to a categorization at the case company, the potential suppliers may include strategic suppliers, preferred suppliers, approved but not preferred suppliers or totally new suppliers in cases of new technologies. All of these may require different approaches depending on trust, history and familiarity of ESI collaboration. Moreover, depending on the technology the suppliers can be categorized to be specialized in designing and manufacturing certain modules or as more generic contractors. When considering special materials and manufacturing technologies the risk to get locked in to the supplier should be acknowledged. As expressed by many participants in the research, the wish is to do ESI collaboration with trusted suppliers. However, sometimes in the projects needs emerge to try out a new to the case company technologies and always these might not be available at the trusted suppliers. In these cases more attention should be paid to risk analysis of the technology, supplier and extent of sharing information to avoid getting locked into a supplier specific technology,

selecting a financially unstable supplier and information leakages. If new to the case company technologies are needed it is likely that also a new supplier is needed which implies that there does not exist trust and business ties between the companies.

Table 4.2. *Supplier categorization considerations*

- Specialized suppliers vs. common contractors
- Strategic partners informed about ESI
- Other preferred suppliers
- Accepted of new suppliers

It is likely that determining the potential suppliers is a highly straightforward process in most cases since the case company is focusing its sourcing efforts to a shortlist of preferred suppliers in the cases of known technologies and this typically is the case with mechanics, PCBA and cables. However, it should still be considered whether those preferred suppliers are capable, willing and available to answer to the pre-defined needs. Strategic sourcing categories should be consulted to find out about strategic reasons for selecting a certain supplier or about issues preventing the selection of a certain supplier. Strategic sourcing managers have the most up to date information about the overview of the current status of a supplier. Already when there is an idea of potential technology alternatives the most suitable volume suppliers should be determined for those technologies. Moreover, there may be reasons to centralize or decentralize sourcing for strategic reasons which influences supplier selections. With all technology-supplier combinations it should be ensured that the technology will be available for the lifetime of the product.

Evaluating the need for involving a supplier

It is likely to be beneficial to receive some amount of information and input from suppliers in all cases when unique parts are developed to be manufactured by a supplier but it should be determined which ones are the critical parts or assemblies where the effort in ESI collaboration should be directed considering resource and capability limitations. With less critical items some elements and principles of the ESI model could be practiced without a formal kick-off meeting. For example informal preliminary inquiries from the suppliers, manufacturability feedback and anticipating prototyping could still be practiced given that the supplier is motivated for such activities.

As seen in the results there may be various reasons for involving a supplier and giving them increased responsibilities regarding the project. The key in managing ESI is to determine whether there appears to be a need to involve the suppliers early or if it would be beneficial when taking into account several factors within the project and product.

To evaluate the need per part a list of critical issues was created based on the factors that suggest that the part might benefit from ESI. Although the need for design support stems from the capabilities of both companies in relation to the part developed, other factors should be considered as well. It may be necessary to involve the supplier early from the need to reduce supply risk by making sure that the deliveries come on time and that the supply chain plays together well. Key things that are related to the need to involve are presented in table 4.3. The idea is to consider what benefits are sought by ESI in each case.

Table 4.3. *Critical issues to consider regarding the need for ESI*

1. Technology specific indications
    a. Manufacturing technologies with molds
    b. New components for PCBAs
    c. Surface treatments
2. Criticality in terms of design related risks
    a. Is the item critical in terms of functionality or quality?
    b. Is the technology new to us?
    c. Do we have the required knowledge in-house and does our supplier have complementary or superior capabilities?
    d. Are there strict quality requirements and specifications?
3. Criticality in terms of time and schedule
    a. Do we have enough time and resources to develop the item?
4. Criticality in terms of cost: cost critical project, cost critical part, volume and business impact
    a. Can we seek supplier input to achieve cost targets?

At the case company it was seen that in design sense there are certain technologies for which it is especially beneficial to involve the supplier early. With mold involved in the manufacturing technology it was seen that the supplier should always be involved early. Additionally manufacturability input was considered essential when there are new components involved in PCBAs and when dealing with surface treatments. These considerations give idea about what activities should be carried out with and by the supplier, when the suppliers should be contacted and what things should be stressed. It may also be determined that a certain part is not critical. The list of these technologies is not comprehensive but gives an idea that certain technologies always imply more need for ESI.

One should be able to determine what the key goals for ESI in a certain project are. Mitigating the pre-mentioned risks aim to ensure short term efficiency and smooth collaboration with suppliers leading to a successful ramp-up of a product. However, also

long-term goals need to be addressed and mutual learning may be one of the key drivers for ESI.

Extent of supplier involvement and role

It should then be determined to what extent the supplier will be involved referring to the role and responsibilities that the supplier would be assigned with based on the need. These decisions are made on the project level but the general "design-or-buy design" decisions should be outlined on a strategic level similarly as with make-or-buy decisions. PCBAs and most of the mechanical parts are considered to be closely related to the core competence of the case company and therefore it is wanted that their design work is maintained in-house. Majority of the case company's ESI cases are likely to be to the extent where a supplier is given responsibility of providing consultation on the case company's designs. This also means that IPRs or document ownership issues would not be relevant in these cases since no direct design work is provided by the supplier. Therefore with these parts the suppliers' role would be to provide consultancy regarding for example manufacturability. It is likely that with for example injection molding there is a need for more intense collaboration of this type in comparison to a machined part.

With cables, enclosures and special modules or assemblies which are outside of the core design competence or for which there might be a specialized supplier with design capabilities and resources there may be potential for giving the suppliers increased design responsibility. The design efforts could be joint to some extent. Suppliers which are specialized to certain structures or specialized applications are more likely to have more design capabilities and resources. If increased design responsibilities are given to a supplier, document ownership issues and possible IPR issues should be addressed.

It would appear that in rather rare cases it would be possible to give suppliers the main design responsibility for some part in ESI collaboration since that type of modules for which there exists a specialized supplier are rarely needed. These cases are rare and the suppliers of these technologies are likely to be new to the case company. This type of involvement might come into question in cases where there is a distinct module which the supplier can design independently based on the case company's functional specifications. Enclosures and special modules that are outside of the company's core competence might be such parts.

The extent of involvement also has implications on what type of resources is required from the supplier since it is likely that increased design responsibility requires closer and more frequent communication and collaboration. Therefore for example some extent of co-location of employees might come into question if high design responsibility is given to a supplier. This should be planned internally and agreed together with the supplier.

Agreeing on communicating with the suppliers

In order to clarify the roles in communication and ensuring that too much information is not given to suppliers or that they are not promised too much, communicating with the suppliers should be agreed upon within the project. The suppliers to contact should be ones that are potential volume manufacturers for the part and therefore the project should consult with the strategic sourcing categories in order to get the strategic viewpoint for supplier selections even in cases where there are several identified manufacturing technology options. The existence of signed NDAs should be ensured before sharing information with a supplier.

Table 4.4. *Guidelines for supplier communication*

- Sourcing project manager facilitates communication with suppliers
- Agreeing on suppliers to contact
- Who discusses with the supplier and about what
- What information is given to the supplier considering the trust towards the supplier and what is expected in return
- Honesty and openness about the situation is key

The approach should be chosen case-by-case depending on the phase and the options in technologies and suppliers. It was determined that sourcing should handle the commercial aspects while design engineers should communicate directly in technical matters. It is possible that there is no need to contact several suppliers if there is a certainty about the technology and supplier selection.

Engaging the suppliers for gathering information and reducing alternatives

Uncertainty about technology feasibility and selection was one of the key things where involvement from suppliers was considered beneficial. The case company often deals with situations where there are several alternative technology options available and due to uncertainty in requirements definition the case company cannot commit to a certain technology too early in the process. There may be several providers of the same technology or several competing technologies. In such cases the suppliers could be engaged in the process of gathering information and reducing alternatives and uncertainty by seeking information about new technologies and materials available, feasibility, preliminary prices, schedule and capacity information. It should be openly communicated to the suppliers if there is still uncertainty about the technology selection. In terms of price information this could include preliminary inquiries about budgetary prices based on the design information and documentation available. Sometimes it might be a more straightforward process to select a supplier when there is less uncertainty about the option or if not many options are available. The goal here is to

gather information and to come to a conclusion about the most suitable technology and supplier to be able to select the expected volume supplier as early as possible. This type of informal information gathering at an early phase is already beneficial in reducing uncertainty and supporting decision making as compared to attempting to figure everything out in-house.

Supplier selection for involvement

A key challenge with the case company is when the design is mature enough and when is there enough knowledge to select the most likely final supplier. Uncertainty about the final technology selection limits initiating close collaboration with a certain supplier since it would not be beneficial to select a certain technology and closely involve a supplier when drastic changes might still be expected due to unclear requirements. Therefore there should be a rather good certainty that the technology will not be changed before moving onwards to a kick-off meeting with the supplier. It is the key idea to involve a supplier that is the most potential volume candidate for the part and therefore such supplier should be found early. The participants of the concurrent engineering process set their own requirements to the design material and specifications which may lead to design changes. This challenge is illustrated with example participants in figure 4.13.

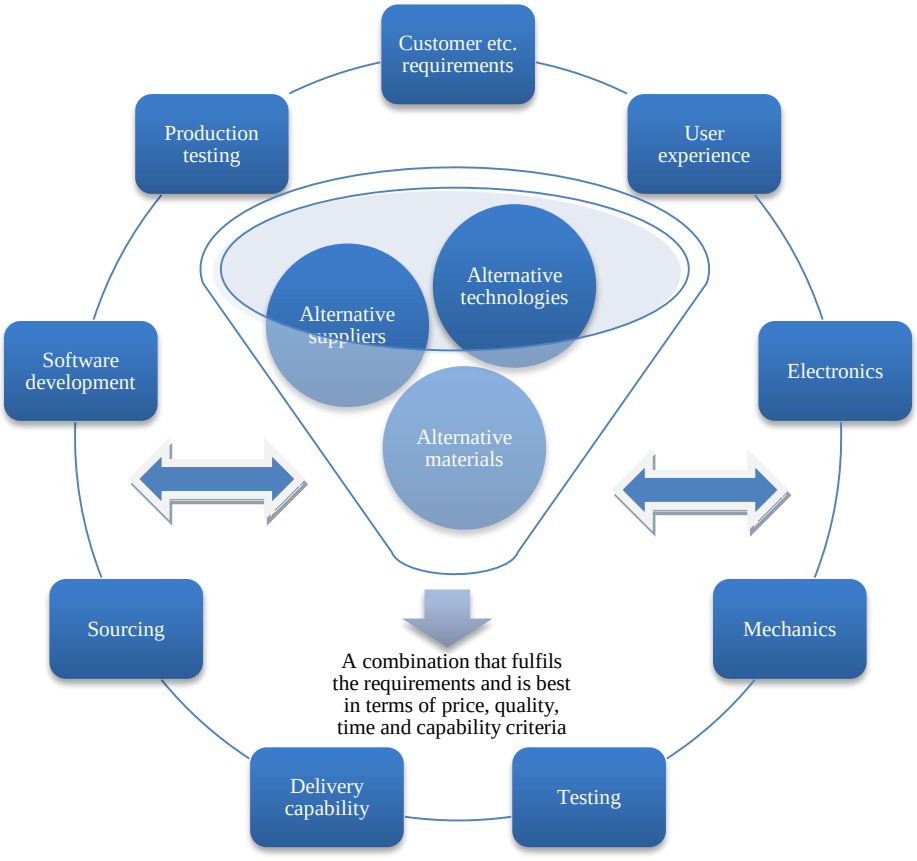


Figure 4.13. *The entwinement of requirements set by several stakeholders and possibilities and limitations in the supply market*

In the middle there are alternative suppliers, manufacturing technologies and materials. These offer possibilities and limitations which are assessed against the requirements of several development process stakeholders, customer requirements and other requirements. The stakeholders on the circle represent the fact that there are several points of view to be taken into account in design work simultaneously. When enough information is available regarding the design it should be possible to select the expected volume supplier for involvement based on the preliminary information received from the potential suppliers. The final solution should be the one that is best in terms of matching the requirements and targets. Regarding costs, total cost should be the determinant to consider instead of only looking at the purchasing price.

The approaches in electronics and mechanics are rather different most likely due to the fact that in mechanics there is more uncertainty about the material, part structure and manufacturing technology whereas in electronics PCBAs are modules that do not have so many variables open in terms of manufacturing which makes supplier selection more straightforward. Uncertainty about the final technology selection prevents the company from selecting the final supplier at a very early stage in mechanics since there is a high variety of technologies and materials to choose from whereas in electronics the PCBAs are typically rather basic in terms of manufacturing technology.

Kick-off with the expected volume supplier

After the expected volume supplier has been selected it should be involved in the development project with the intention of building up production and delivery capability together and taking the supplier's viewpoints into account in design work. A kick-off meeting should be arranged to formally initiate the collaboration and to share information. The agenda for the kick-off could include discussing and agreeing on the following:

Table 4.5. *Possible agenda for ESI kick-off meeting with a supplier*

- Information about the product and project: goals, schedule, requirements, functionality, expected annual production volumes, product's critical features
- Preliminary price information, capacity, materials, opportunities and limitations
- Meeting and follow-up practices
- Expectations towards collaboration
- Project contact persons and information, also other relevant supplier contacts

The kick-off provides a chance to generate a common understanding about how the collaboration will be carried out and it offers the chance for both parties to express their own points of view. For the suppliers receiving information about the project is beneficial since it helps them to better provide support and suggestions when the big

picture and requirements communicated. In the long term it helps in improving the understanding about the case company's products and business. Common worries should be addressed if the participants are not familiar with ESI practices. It should be made clear that the goal is to aim for volume production together which would offer mutual benefits. This implies that the case company would not plan to change the supplier but on the other hand nothing is guaranteed for the involved supplier. Collaboration should flow according to the commonly agreed plan, solutions provided by the supplier should be universal and prices should not end up rocketing when moving towards production. There should be grounds for changing the supplier and therefore a common view and open discussion about collaboration and prices are needed to avoid damaging the relationship.

Coordinating co-design collaboration with suppliers

According to the agreed plan and based on ad-hoc needs there should be joint status updates and project follow-up practices during the development project. Status updates should include information about needs to make changes to the design's previous revision and updates on design maturity to for example determine when it is a suitable time to move on with a mold order regarding injection molding. Problems and major influencing events such as schedule changes and contact person changes should be informed about by both parties. Additionally, schedule and price information should become clearer throughout the project and both parties should be kept up to date in these matters. Status updates could include for example prototyping schedules, giving feedback both ways regarding collaboration, discussing designs, connecting first tier and second tier suppliers or first tier suppliers of certain technologies. Part of the process could be reviewing design features together both in terms of supplier's processes and costs to detect features that are costly and to understand the manufacturing process effects of a certain feature. In cases where it is decided that a supplier could be given increased design responsibility some extent of engineer co-location could be exercised.

Sharing preliminary information should be a systematic part of managing ESI collaboration especially with regard to prototype needs. In electronics this would mean sending a preliminary list of components (pre-BOM) to the supplier already when the design is not complete so that the supplier can ensure component availability, purchase and acquire the components and reserve capacity for prototype manufacturing. In mechanics a similar method would be to share preliminary designs to be reviewed and commented by the supplier in terms of manufacturability while also reserving material and capacity for future order. This also requires setting a deadline for the finished design for prototype manufacturing. Additionally, assembly drawings could be provided to give the supplier a better understanding of the total system. These methods require a proactive attitude and open information sharing within the project facilitate information sharing to the supplier. These practices are illustrated in figures 4.14 and 4.15.

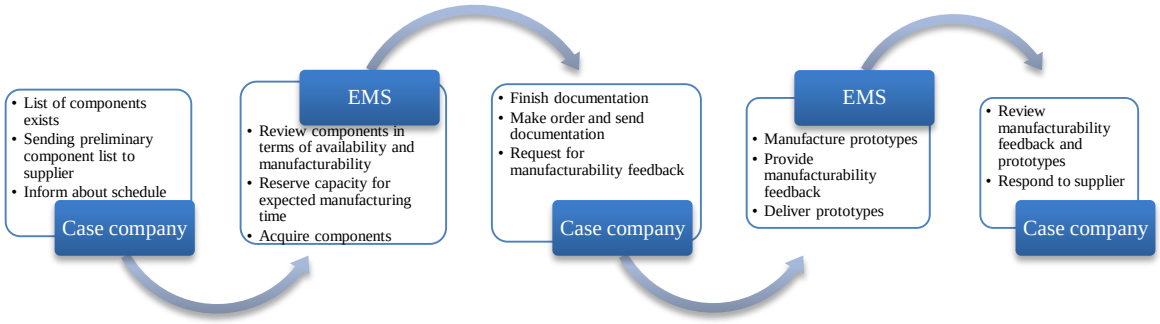


***Figure 4.14**. Pre-BOM practise and manufacturability feedback practice concerning PCBAs*

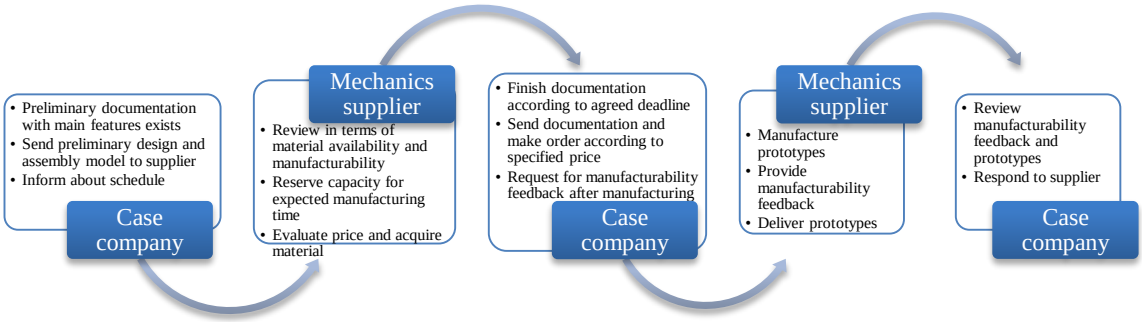


***Figure 4.15.** Prototype anticipation and manufacturability feedback practice in mechanics*

Joint decisions made should be documented and especially manufacturability feedback document should be utilized when necessary after prototypes and prototype series. With manufacturability feedback the supplier should report the issues that surface during prototype manufacturing accompanied with corrective actions on their behalf and suggestions for the case company's design. This way manufacturability is formally taken into account already in prototype phase to prevent discovering them late in production. The feedback should flow two ways so that also the supplier will know what actions their feedback caused and why. Also direct feedback should be provided back to the supplier about the prototypes.

It should be taken into account that involving several suppliers increases the amount and complexity of project coordination required and therefore prioritization may be in order to involve closely only the suppliers of the most critical parts. Collaboration between involved suppliers should be facilitated by for example providing contact information if seen necessary and on the other the suppliers may be given more responsibility for managing their supply chain independently. At the end of the project a lessons learned session should be arranged to reflect on how the collaboration went and what could be improved.

It may be challenging to anticipate when exactly different activities should be carried out and therefore it makes most sense to view supplier and sourcing activities as a part of the product development process. It is likely that timing of supplier involvement cannot be planned in advance due to uncertainty about the progress of the development process. Therefore the need to involve and seek input from the supplier needs to be determined during the project. For a more development process bound depiction of sourcing and supplier activities regarding ESI, sourcing and supplier activities should be aligned with the product development process and design activities. These activities could be considered as individual process modules with certain activities at each phase due to the high amount of flexibility in the concurrent product development process. Throughout the development process sourcing needs to remain active in facilitating the collaboration with the supplier.

4.4. Discussion

4.4.1. Assessing the results of the study

The research objective was to develop a systematic model for managing ESI in NPD for the case company. The corresponding main research question was presented as “what are the elements that managing early supplier involvement in new product development comprises of?“ and it was divided into two sub questions. The first sub question was introduced as “what are the critical factors that influence the need and form of early supplier involvement in new product development?”. This was answered in the synthesis of the theoretical background while also the results of this study provided insight on the factors that were considered relevant at the case company and that there is a vast variance in these factors. The second sub question was “what are the key activities and considerations in managing early supplier involvement in new product development at the case company?”. A systematic model that covers activities and things to consider at the case company in managing ESI was presented in the results to answer the second sub question. The perceptions of ESI were highly scattered and hence this study provides a structured way of understanding ESI at the case company. The model does not give full instructions but instead provides a systematic way of selecting the most suitable approach in practical management. A lot of responsibility is therefore in the hands of the ones responsible for managing ESI to study, learn, apply and improve the practices. At the starting point of this research several of the typical barriers and worries presented in previous research (Wynstra et al. 2001; McIvor et al. 2006) were also present at the case company while several prerequisites were also established or put under development based on the sourcing strategy during the research.

Comparing the influencing factors found from the literature to the case company’s context, there is a huge variance among the influencing factors in the case company’s product development projects due to the high mix – low volume operating model. Several of the factors mentioned in workshops are well in line and backed up by

previous studies since similar findings have been published before. The factors found from literature appear to be suitable determinants to consider in product development projects when selecting a suitable management approach although in this case the great variance in the factors poses a challenge for management. Studying the management of ESI in high mix – low volume context turned out to resemble as if there were several companies and contexts under study as the products and product development project are so different from each other and therefore the influencing factors are highly manifested. It would appear that uncertainty has a major impact on all the decisions and actions regarding ESI since technology and supplier selections are then not at all straightforward.

With regard to the spectrum of supplier involvement by Petersen et al. (2005) the case company's ESI is mostly white box type of collaboration since majority of design work is maintained in-house and the key suppliers are contractors with limited design capability and resource. It is with these key suppliers that there is the best chance for a long term trust-based relationship which best supports successful ESI activities. Therefore in most cases it is essential to involve the suppliers to consult on the designs in manufacturability, material and component sense and to provide information regarding for example possibilities, limitations and feasibility at early phases of development. The aim is to make this type of collaboration systematic and close. However, there have been cases where grey box and black box type of collaboration have taken place but in those cases the suppliers have been suppliers specialized in certain systems or modules. The potential in this type of collaboration should be kept in mind especially with more specific modules such as cables and harnesses and enclosures.

Literature has given propositions that suppliers should be involved at different stages of product development project (e.g. Handfield et al. 1999). For the case company it would appear to be most suitable to involve the supplier when needed and as early as possible since it is often difficult to determine beforehand what type of technologies are required. The timing highly depends on the requirements definition: when it is known that a certain technology will be needed in the product. Different kind of input may be needed at different stages of NPD. Literature suggests that the white box type of suppliers should be involved later on in the process but the research proposes that even this type of suppliers could be engaged already quite early in the process to seek information. A different issue is when the actual supplier selection can be made.

Van Echtelt et al. (2008) and Handfield et al. (1999) suggested that suppliers could be pre-selected or pre-qualified for involvement in NPD. As suggested by Melander (2014) there may be a need to gather information of potential suppliers to manage uncertainty during a project especially if a new supplier is needed. The studies by Zsidisin and Smith (2005) and Langner and Seidel (2009) presented that the suppliers could be challenged through a concept or design competition. However, with the case company's

low volumes and supplier base such case competitions do not appear realistic but instead preliminary information and suggestions could be gathered in a more informal way. This study suggested that with the well-known suppliers the supplier should be "pre-selected" for involvement, that is, the aim with involving a supplier should be to achieve the best result together and select that supplier for the volume business. In selecting the supplier the maturity of the design appears to be the key factor when considering the final volume supplier. Under uncertainty and with new suppliers a more careful approach to supplier selection should be applied.

In line with the studies by Eisto (2010) and Melander and Lakemond (2015) suggest, due to uncertainty, need for new technologies and new or not so well-known suppliers in a project there might be needs for different types of ESI business model and partnership or transactional based governance. At the case company, it appears that there are sometimes needs to involve suppliers with whom there is no existing business and trust-based relationship and therefore the collaboration might sometimes be on transactional basis. With established partners the collaboration should be based on trust and therefore gaining the volume business and being able to affect the design should be the grounds for ESI. With new suppliers it might be reasonable to pay for consultation if a lot of input is needed from the supplier, the case company does not want to commit to the supplier early and if the supplier cannot trust to receive any benefits of their provided input.

Wynstra and Ten Pierick (2000) suggested that different communication methods should be applied with different levels of supplier responsibility and design risk. This study supports this view as it was seen that the frequency and openness in communication should be chosen case by case. Compared to the coordination methods presented by Lakemond et al. (2006), for the case company the most suitable methods would be mainly a combination of project integration coordination and ad-hoc direct contact. This can be argued since it was seen that ESI collaboration should begin with a kick-off meeting and continued by follow-up practices and the technical experts are hoped to be in direct contact when needed. Decoupled coordination might come into question if the design work of a certain module would be outsourced to a supplier. Especially with involving strategic and preferred suppliers, the goal would be also to build long term benefits instead of just aiming for short term efficiency. With regard to the supply chain coordination strategies by Johnsen (2011) it was seen mutually beneficial by the suppliers and the case company that intervention strategy would be applied to connecting involved suppliers together and making collaboration possible between those suppliers. The case company's aim in the future would also be to apply delegation strategies by giving their trusted suppliers increased responsibility in managing sub-suppliers. Sharing preliminary information about designs and components to the suppliers also falls into delegation type of coordination.

The model presented as a result of this research has several similar steps as in the operational arena of the IPDS model by Van Echtelt et al. (2008). Therefore two important observations can be made. First, the case company has such a vast variety of different projects and project circumstances that only rather general instructions can be given to support managing ESI instead of a strict process to follow. However, this can be considered natural since the company follows a concurrent product development process which also allows for several degrees of freedom since it has to fit all of case company's projects. Therefore this study suggests that the supplier activities and sourcing activities should be considered alongside other development activities in the concurrent product development process. Second, the IPDS framework appears to be rather comprehensive and general enough illustration about the considerations that should take place both on the strategic and operational arena. It may be beneficial for companies that seek to establish systematic ESI practices to study the model although the practical adaptation is likely to be different in different organizations.

4.4.2. Academic contribution

Being a single case study that was designed and implemented as action research based on the case company's specific need and context, the study's contribution to the academic community can be considered rather minor. However, the study did contribute by describing the development process of a systematic model for ESI in NPD. Additionally, literature was gathered to provide an understanding about the factors that should be considered in managing ESI what might be beneficial for both practitioners and academics familiarizing themselves with the topic of managing ESI in NPD. These factors could be used to explain why a company ends up using a certain form of supplier involvement and how the practices could be improved. It appears that managing ESI has not been studied in high mix – low volume context and this way the study contributes to theory. Moreover, the study also took into account the suppliers' points of view.

In a way, the case company's situation regarding various different product projects resembles that of managing ESI in various company contexts and therefore this context appears to reveal a huge variety of considerations that influence the need and form of ESI. Therefore the practical management of ESI at the case company may include the whole variety of different degrees of supplier responsibility and different coordination methods. Academics should pay more attention to the type of product development projects and technologies related as well as the type of suppliers the buying company is dealing with when studying ESI on a general level since industries such as the automotive industry might give too simplified a picture about managing ESI. As such, the ESI practice development process and model presented in this study appeared to be aligned with previous research and the findings of this study and previous studies supported each other.

4.4.3. Managerial implications

This study generates several managerial implications especially for the case company but also some generally interesting implications are brought forth. At the case company, top management support needs to remain strong and active for the culture to change within the case company and at the suppliers. Based on the process of developing the ESI model for the case company the role of top management commitment and cross-functional collaboration between sourcing and R&D cannot be stressed enough. It appeared to be a good approach to involve the key stakeholders in developing the practices as this distinctly verified the fact that the stakeholders commonly agreed on the practices bringing forth the question why such closer collaboration has not been done before. It does appear to require strategic alignment of sourcing, R&D and suppliers and without such efforts the practices would be likely to fail or spread slowly.

To further support the practices, ESI should be integrated to tools and checklists and arranging training and promoting ESI need to be continued within the organization and with the suppliers. Management is in a key role in driving the change. Supplier development should focus on capabilities and related resources and should be done more intensively with key strategic suppliers. For ESI to work the nature of concurrent engineering needs to be embraced and the success of the product development project needs to be seen as the responsibility of all participating members, not just the engineers. However, there needs to be a driving force and facilitator to ensure ESI and make it easy to collaborate across company borders. It is recommendable to start piloting with a few key suppliers who were defined selected as the initial ESI partners during the project, gradually expanding to other trusted and capable suppliers and promoting cases of success.

Attention needs to be paid to looking forward in technology trends and needs when developing and selecting suppliers so that the company maintains technologically capable supplier base. Also looking forward in the product project portfolio and detecting whether a new product will include technology for which the suppliers could provide input. It is important to understand the most critical factors with regard to the most commonly needed materials and technologies. If in the future the case company deems it necessary or beneficial to involve its key suppliers even more closely in its new product development projects by giving them design responsibility and to make that a more systematic practice, the following things might be required:

1. Increased supplier capability and resources to take on design responsibilities and actively participate in NPD as a project member.
2. Deciding on technologies for which design work can be outsourced. This might be necessary out of capacity needs, if the technologies are considered out of core design competence or if a supplier has superior design expertise.

3. Clear modules for which to give design responsibility for the suppliers (modular architecture).
4. Training supplier design engineers to the case company's context.

This study presented a real life case of company striving to develop and enable ESI practices which may be interesting for other companies interested of such endeavors. Companies considering ESI activities should first analyze their current practices and their company specific factors that sets the frame for the first steps of establishing ESI practices at the organization. The whole sourcing organization should be aligned in a way that supports integration with product development and consequently supplier involvement and therefore strategic changes may need to be made. That company should prepare to put time and effort into planning and promoting the concept depending of course on the initial situation. It should be determined how much responsibility can and is wanted to be given to suppliers regarding design efforts and what capabilities the current key suppliers possess. A low volume company does not have the muscle to simply pick any supplier available in the global supply market and therefore efforts may need to be put more into developing existing suppliers instead of looking for new ones. It might be beneficial to study how such influencing factors that were presented in this study are present at the company and what implications they hold for the company.

4.4.4. Limitations of the study

The research came close to being ethnographic by nature as the researcher was very closely immersed in the activities of the case company and involved a vast group of major stakeholders in the research (Saunders et al. 2009, pp. 149-150). The researcher participated in two product development projects, interviewed and conducted workshops with participants from R&D, sourcing and suppliers, was able to browse the company's internal sources of information, had informal discussions with several people and participated in various meetings, trainings and development sessions. The results appear to be sufficient in serving the purposes of the case company as the objectives were reached and questions answered. However, the study has multiple limitations and therefore its credibility in terms of validity and reliability must be critically assessed (Saunders et al. 2009, p. 156).

Reliability refers to the degree to which the research findings are consistent in cases where same data collection techniques and analysis methods are applied. Reliability therefore deals with whether the same methods provide the same results in different occasions, whether other researchers would make the same observations and whether it is clear how the conclusions are reached based on the presented data. (Saunders et al. 2009, p. 156; Easterby-Smith et al. 2008, p. 109.) This study is a single case study that was carried out as action research and therefore the academic contribution is rather minor. The research objectives, questions and methodology were based on the needs of

the case company and therefore repeating the research in different companies would probably provide different results at different times. The research procedures were described in detail previously in this study and it should provide the possibility of replicating a similar study in similar fashion. However, especially the supplier workshops were carried out by different facilitators in different methods reducing the reliability. More specifically, reliability can be assessed in terms of interrater reliability, test-retest reliability and internal consistency reliability (Trochim 2000).

An aspect of reliability assessment is interrater reliability which refers to the extent to which different individual researchers agree on the results. (Trochim 2000) This research was carried out by a single researcher as action research and therefore it is most likely that the presence of the researcher had an effect on the results. It was not possible to have several researchers with whom to compare the results and see if the same conclusions were drawn and additionally the contents of the qualitative data gathering processes were rather flexible which makes it difficult to assess interrater reliability. It can be seen that in the workshops' interrater reliability is sounder since there were several participants who can be seen as initial validators for the discussions and results whereas the semi-structured interviews were one-on-one events.

Test-retest reliability refers to repeating the same test multiple times over time (Trochim 2000). Each individual was interviewed only once but some of the interviewees also participated in the workshops. The workshops were a group effort and the agenda was different compared to the interviews so it is not possible to compare the consistency of the individuals' input in these two methods. Additionally, it is possible that the research process and ongoing changes at the case company might have had impact on the results. Test-retest reliability can therefore be assessed rather tenuously.

Internal consistency refers to the degree to which the items on a test are related to the other items of that test which can be evaluated in calculative methods with for example average inter-item correlation or split-half reliability calculations (Trochim 2000). Quantitative methods were not used in this study and on the other hand the study was not about testing a theory or interrelations of different items. Therefore assessing internal consistency of the study is challenging.

The reliability of this research may also be threatened by subject error and bias and observer error and bias. Subject error and bias stem from the participant or subject of the research. (Saunders et al. 2009, pp. 156-157.) Subject error could be cause by for example observing the participants at a non-neutral time such as early Monday mornings or late Friday afternoons. This aspect was not given particular thought but it is not likely to have had a major effect on the research as the researcher was able to be present face-to-face and to lead the situation. In terms of subject bias, it is possible that the participants may have been affected by the study leading to them altering their answers to avoid what is in their opinion disadvantageous development in the

organization or a threat to them personally. For action research it is natural that the participants of the research are biased as research happens in action and drives change.

Observer error and bias are caused by the researcher. Observer error to the results of this study might have been caused by the interviews being semi-structured as well as the workshops not being strictly structured. This leaves a lot of different ways for researchers to maneuver within the themes and conduct the interviews and workshops in their individual way, potentially resulting in different answers. This threat was mitigated by planning the interviews and workshops ahead and creating a set of themes and questions to guide through the events. Observer bias was a risk since the researcher might have been biased towards seeing positive attitudes towards change when interpreting the results of the research as inducing change was also a part of the goals. It is also possible that other researchers might interpret the gathered data in a different way. This threat was tackled by recording the interviews and one of the workshops, rigorous transcription of the audio and writing full descriptions of the discussions based on notes immediately after the events. Having the interviews and workshops face-to-face provided a better possibility to study the participants' attitudes and body language to better understand the underlying thoughts.

Validity in general refers to the research findings being what they are expected to be about or in other words how well the results match the measured phenomenon. Several issues may pose threat to the validity of a research (Saunders et al. 2009, p. 157.) In this study, history probably has a significant role to the results since some of the interviewees also participated in the workshops and additionally other activities such as ESI trainings and presentations took place to increase awareness and knowledge in the personnel of the case company. Therefore it can be stated that the participants of the study were increasingly biased with regard to the topic but on the other hand driving change is typically the goal of action research. This can, however, be considered significant for the validity of the study since the results are likely to be influenced by the change driving atmosphere at the case company. At the time of the interviews the whole ESI concept had not yet been introduced as a strategic direction and the awareness of the topic was significantly lower. In this sense the interviews can be considered more valid compared to the workshops. It is therefore more likely that the opinions and views had started to converge towards a more common view as awareness increased.

According to Carmines and Zeller (1979, pp. 17-26) a study should be assessed in terms of criterion-related validity, content validity and construct validity. Criterion-related validity refers to assessing whether the chosen research methods are accurate compared to other valid research methods (Carmines & Zeller 1979, pp. 18-20). Direct comparison to another valid research is challenging since the research was carried out in one case company with a specific context. In terms of research methods and strategies, semi-structured interviews and action research are typical methods used in valid researches. Workshops are not among the most typical methods and therefore they were

described in more detail. However, group interviews and focus groups are among commonly used valid methods (Saunders et al. 2009, pp. 345-346) and the workshops arranged were rather similar by nature. It was also possible for the researcher to assess the validity of the findings in practice by participating in two product development projects.

Content validity refers to whether the results represent what was intended to measure (Carmines & Zeller 1979, pp. 20-22). As presented above in discussion section, the research questions were answered and objectives achieved and in this sense the content validity appears good. However, although many stakeholders were involved in the research process it was impossible for the researcher to involve people from all business segments or to get a fully comprehensive idea about the variety of different projects and products at the case company in the time frame of the research. Equally challenging was attempting to cover several technologies and several different types of suppliers in the given time since there is a vast variety of these as well. This is why the results were presented on a rather general level and still it may possible that they do not cover all cases that the case company comes across. The practices need to be highly adaptable to different situations.

Construct validity refers to whether the research methods and results are in line with a theoretical concept (Carmines & Zeller 1979, pp. 22-26). Based on the theoretical background a conceptual framework was created to illustrate the factors that influence managing ESI as well as the key activities that it influences. In this study several theoretical concepts and frameworks were introduced and as presented in the discussion section the elements of these concepts are also present in the results and they can be utilized to explain different ESI management approaches at the case company. In this study ESI definitions by Bidault et al. (1998) and Van Echtelt et al. (2008) were applied and additionally ESI was considered as a set of internal and external activities to enable product development collaboration in new product development projects. This study shed light on the type of input and resources that the case company's would want their suppliers to have and provide and also what some of the suppliers would be willing to provide. Additionally, activities carried out internally and across company borders to manage ESI collaboration were addressed in the results. The results appear to agree with the theoretical background presented. However, a single framework appears to be insufficient in covering the whole of the ESI phenomenon as it is a strategic concept that requires alignment on several organizational levels, in several departments and across company borders. It might be beneficial to assess ESI as a strategy due to the broadness of the topic.

It is also likely that the confusion around the concept under study might have influenced the results since at times there did not appear to be a clear understanding about what exactly can be considered ESI (which technologies are concerned, what constitutes 'early', what type of involvement is in question) and what kind of changes it would

bring in the company's practices. Especially due to the high mix of products people had experiences from only certain product areas and therefore probably no one had the comprehensive view about all kinds of projects, products and technologies. It appeared that sometimes when discussing ESI all collaboration and activities with suppliers during a product development project could be regarded as ESI. However, this can be seen as beneficial in a way since different points of views and related topic came into light. This also illustrates the fact that the concept of ESI was rather new to the company and part of the research process was generating the understanding about what it means for the case company in particular. With the second internal workshop not all the invited participants were able to participate and therefore the results can be considered less valid as compared to the other workshops. The interviews and workshops were carried out in Finnish implying that some information might have been lost or skewed in translation to English.

Additionally, generalizability, also known as external validity, and logic leaps and false assumptions should be evaluated critically. Generalizability refers to whether the results of this study are applicable to other organizations. (Saunders et al. 2009, p. 158.) The results of this study are not likely to be generalizable to other organizations since the whole study was planned and carried out based on the case company's need and to best answer the research questions based on that need. Statistical generalizations to cover the whole research population cannot be made from the qualitative data which in this study was gathered by semi-structured interviews and workshops since the total number of participants in the study was relatively small (Saunders et al. 2009, p. 327). However, nothing would prevent testing the fit of the results in some other settings.

Logic leaps and false assumptions on the other hand relate to making sound research selections in terms of identifying the research population, collecting and interpreting data and developing the conclusions based on clear logic (Saunders et al. 2009, p. 158). The research population in this study was the case company and the idea was to be able to provide results that are generalizable to that population. It remains to be verified in practice whether the results actually fit all the cases of the case company but the goal was never to produce generalizable results to several organizations. In data interpretation and when planning the research theories were utilized to make sense of the data in a structured way. Therefore the theories studied had an impact of both how the research was carried out and how the data was interpreted. The time period for the research was rather short and the topic vast and therefore it is possible that theories could have been utilized in a better way. The researcher did not have enough time to thoroughly cover all the theoretical background in the early phases of the study and therefore the comprehension of the theories increased only as the research progressed. Regarding logic leaps, the researcher had access to such vast amount of data through action research that not everything could be documented and therefore it is likely that the final results include conclusions that cannot be drawn just based on the interviews

and workshops. Verification and input from the researcher's supportive groups increases the validity from the case company's perspective.

5. CONCLUSIONS

5.1. Research summary

The successful involvement of suppliers in product development may enable competitive advantage through several benefits as a natural continuation of the concurrent engineering process. ESI is first and foremost a strategic concept and a mindset that requires alignment of several departments on several levels, and a cultural issue in terms of willingness and trust to collaborate across company borders. Having a systematic model makes it easier for the people managing it to take into account the relevant matters but it is still up to several managers and stakeholders to facilitate, support, develop the practices and collaborate to succeed. The model is a starting point and can further be refined and modified as the company becomes more experienced in ESI practice.

The objective of this master's thesis research was to provide the case company with a systematic model that supports managing early supplier involvement in new product development projects. The model was required to be general enough to fit all of the company's product development projects and therefore it had to provide rather general instructions about the things that should be taken into account at the case company in each project. Such model was constructed based on answering the research questions that dealt with the factors to take into account and the activities carried out in managing ESI on the operational project level. Moreover, the study provided a comprehensive view to the case company's ESI context in order to understand what limitations and possibilities there are in terms of supplier collaboration. In the process four initial ESI partners were selected.

The key principles in managing ESI at the case company can be summarized as follows:

1. Open and honest communication is key – sharing information as openly as possible internally and externally
2. Sourcing drives and facilitates ESI making collaboration easy
3. ESI approach should be considered on part or assembly level
4. Determine potential technologies actively and as early as possible
5. Evaluate need for ESI as early as possible
6. Determine potential volume suppliers for recognized structures as early as possible
7. If necessary, seek preliminary information from suppliers to support in supplier and technology selection

8. Involve expected final supplier as early as possible and strive for volume production with the involved supplier
9. Share preliminary information and formally kick-off ESI collaboration with suppliers of critical items
10. Connect suppliers that need to collaborate with each other

In practice the creation of this model means that the case company's sourcing project managers now have a systematic way to take ESI into account and drive it as participants of product development projects and the means to justify their decisions with. The model provides a good starting point for adopting a new mindset towards supplier collaboration and driving the ESI agenda in projects and further refining the collaboration practices with suppliers. In the process several stakeholders were involved in developing these practices resulting in increased awareness of ESI and strategic sourcing objectives further facilitating adopting the practice. It remains to be seen what type of advantages will follow when the organization and new product development projects become more oriented to the idea of involving suppliers early and doing deeper trust-based collaboration with them.

In the creation of ESI practices the starting point with current practices was first analyzed. In literature several barriers, enablers and success factors to ESI and related to a company's internal practices, suppliers and buyer-supplier relationship were discovered. Also at the case company several of these known barriers were present while several conditions were also supportive of ESI. Several of the barriers were tackled by the sourcing strategy and related practice development projects. The contribution of this research to the strategy was managing ESI on the operational project level. From literature factors that influence the need for ESI and the form of it were recognized. On a broad level the factors were categorized to organization specific factors that can be seen to cause the factors on the project level. The factors on the project level were categorized to be related to the project, part design and technology, supplier and relationship and strategic level considerations. It was found that the variance in these factors at the case company is vast mainly due to the high mix of products and target markets. It was found that the factors have an influence on what responsibilities and activities should be given to and carried out by a supplier, how the supplier selection process would be carried out, how the collaboration coordination and communication should be arranged and what type of business model would be applied to involving and motivating a supplier.

The influencing factors should be recognized and understood on the project level. At the case company there is a vast variance of the influencing factors and therefore the suitable approach should be selected case by case. The systematic model supports in taking these factors into account. The model begins with ESI planning and preparations which aim at discovering the most potential volume supplier to involve to the project. It would be most beneficial to select and involve the final supplier as early as possible to

familiarize them with the project, share information, seek input and coordinate the collaboration. In order to establish an aligned understanding about the activities carried out by sourcing project representative and supplier during a development project, their activities should be aligned with the company's concurrent product development process as individual process modules and suggestions of these activities were presented. It was also illustrated why it may sometimes be challenging to determine, select and involve a supplier at an early phase of product development especially regarding mechanics since there are several technology options open and the requirements that set the frame for selections become clearer as the project progresses. This is especially the case when the project is characterized by high levels of uncertainty.

It was rather interesting to discover that all of the stakeholders involved in this study had such uniform views about the benefits, importance and challenges of ESI. In general the whole concept was seen as a win-win by all stakeholders to both the case company and to the suppliers and yet systematic practices had not been established before. Several of the challenges and threats that many expressed can be partly attributed to the broadness of the topic of ESI and lack of understanding about what it could mean for the case company. The development of sourcing strategy and explicitly selecting strategic partner suppliers helped in determining who should be the suppliers that the practices are safe to pilot with and to intensify collaboration with.

It is possible that a similar approach for establishing more systematic ESI practices could be adopted in other companies but time and effort should be put into analyzing the current state regarding the company, its suppliers and their practices. Even more so time and effort are needed in developing the most fitting approach and implementing it since companies and their context are highly different and change often faces resistance especially if it is not communicated and understood properly.

5.2. Future research

In the future it would be interesting to see studies regarding ESI from the viewpoint of suppliers as that sort of research appears to be scarce. Perhaps the lack of such studies indicated that supplying companies have not recognized the business opportunities and the benefits as clearly as the buying companies or perhaps the more traditional transactional ideology is more deeply rooted in supplying companies. It is also likely that it is the demand and pull from the customer companies that evokes the suppliers to develop certain capabilities instead of the suppliers taking the initiative in developing such capabilities and then pushing them towards their customer companies.

Studying suppliers that seek to become involved to their customers' NPD would provide potentially valuable information to ESI literature. Topics to study could be for example the business potential in this type of collaboration as industrial service

business, studying NPD input as investment to gain more business from supplier perspective or studying what kind of capability would best support a supplier's operations and customers. Additionally, it appears to be extremely difficult to measure the benefits of ESI and it would be interesting to see longitudinal researches that study changes in performance when establishing systematic ESI practices. More attention should be paid in managing ESI in different contexts, industries and with different operations and the differences between these the approaches in these context would be certainly intriguing. It would be interesting to see more focus on the factors that shape the form of ESI in these various contexts providing more insight as to why certain ESI approaches fit certain contexts. It appeared that in literature the relation of ESI and supplier selection in the operational level is also rather poorly covered.

BIBLIOGRAPHY

Afonso, P., Nunes, M., Paisana, A., & Braga, A. 2008. The influence of time-to-market and target costing in the new product development success. International Journal of Production Economics. Vol. 115, Issue 2, pp. 559-568.

Andersen, P. H., & Drejer, I. 2009. Together we share? Competitive and collaborative supplier interests in product development. Technovation. Vol. *29*, Issue 10, pp. 690-703.

Bidault, F., Despres, C., & Butler, C. 1998. The drivers of cooperation between buyers and suppliers for product innovation. Research Policy. Vol. 26, Issue 7, pp. 719-732.

Birou, L. M., & Fawcett, S. E. 1994. Supplier involvement in integrated product development: a comparison of US and European practices. International Journal of Physical Distribution & Logistics Management. Vol. 24, Issue 5, pp. 4-14.

Blomqvist, K., Hurmelinna, P., & Seppänen, R. 2005. Playing the collaboration game right—balancing trust and contracting. Technovation. Vol. 25, Issue 5, pp. 497-504.

Brown, S. L., & Eisenhardt, K. M. 1995. Product development: Past research, present findings, and future directions. Academy of management review. Vol. 20, Issue 2, pp. 343-378.

Campagnolo, D., & Camuffo, A. 2010. The concept of modularity in management studies: a literature review. International Journal of Management Reviews. Vol. 12, Issue 3, pp. 259-283.

Carmines, E. G., & Zeller, R. A. 1979. Reliability and validity assessment. Sage Publications, Inc. Thousand Oaks, California. 73p.

Carr, A. S., & Pearson, J. N. 2002. The impact of purchasing and supplier involvement on strategic purchasing and its impact on firm's performance. International Journal of Operations & Production Management. Vol. 22, Issue 9, pp. 1032-1053.

Clark, K. B. 1989. Project scope and project performance: the effect of parts strategy and supplier involvement on product development. Management science. Vol. 35, Issue 10, pp. 1247-1263.

Cooper, R. G. 2008. Perspective: The Stage-Gate® idea-to-launch process—Update, what's new, and NexGen systems*. Journal of Product Innovation Management. Vol. 25, Issue 3, pp. 213-232.

Cooper, R., & Slagmulder, R. 1997. Target costing and value engineering. Productivity Press, Portland.

Cooper, R., & Yoshikawa, T. 1994. Inter-organizational cost management systems: The case of the Tokyo-Yokohama-Kamakura supplier chain. International Journal of Production Economics. Vol. 37, Issue 1, pp. 51-62.

Das, A., Narasimhan, R., & Talluri, S. 2006. Supplier integration—finding an optimal configuration. Journal of Operations Management. Vol. 24, Issue 5, pp. 563-582.

Dowlatshahi, S. 1998. Implementing early supplier involvement: a conceptual framework. International Journal of Operations & Production Management. Vol. 18, Issue 2, pp. 143-167.

Dubois, A., & Gadde, L. E. 2002. Systematic combining: an abductive approach to case research. Journal of business research. Vol. 55, Issue 7, pp. 553-560.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. 2008. Management research. Sage Publications. London. 368p.

Eisto, T., Hölttä, V., Mahlamäki, K., Kollanus, J., & Nieminen, M. 2010. Early supplier involvement in new product development: a casting-network collaboration model. World Academy of Science, Engineering and Technology. Vol. 62, pp. 856-866.

Fliess, S., & Becker, U. 2006. Supplier integration—Controlling of co-development processes. Industrial Marketing Management. Vol. 35, Issue 1, pp. 28-44.

Frohlich, M.T. & Westbrook, R. 2001. Arcs of Integration: An International Study of Supply Chain Strategies. Journal of Operations Management. Vol. 19, Issue 2, pp. 185-200.

Gelderman, C. J., & Van Weele, A. J. 2003. Handling measurement issues and strategic directions in Kraljic's purchasing portfolio model. Journal of purchasing and supply management. Vol. 9, Issue 5, pp. 207-216.

Gottfredson, M., Puryear, R., & Phillips, S. 2005. Strategic sourcing. Harvard business review. Vol. 83, Issue 2, pp. 132-139.

Hall, J. K., Matos, S., Silvestre, B., Martin, M. 2011. Managing technological and social uncertainties of innovation: the evolution of Brasilian energy and agriculture. Technological Forecasting and Social Change. Vol. 78, Issue 7, pp. 1147-1157.

Hall, J. K., & Martin, M. J. 2005. Disruptive technologies, stakeholders and the innovation value-added chain: a framework for evaluating radical technology development. R&D Management. Vol. 35, Issue 3, pp. 273-284.

Handfield, R. B., Ragatz, G. L., Peterson, K., & Monczka, R. M. 1999. Involving suppliers in new product development?. California management review. Vol. 42, pp. 59-82.

Hartley, J. L., Meredith, J. R., McCutcheon, D., & Kamath, R. R. 1997. Suppliers' contributions to product development: An exploratory study. Engineering Management, IEEE Transactions. Vol. 44, Issue 3, pp. 258-267.

Henderson, R. M., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. Administrative science quarterly. Pp. 9-30.

Jiao, Y. Y., Du, J., Jiao, R. J., & Butler, D. L. 2008. Operational implications of early supplier involvement in semiconductor manufacturing firms: a case study. Journal of Manufacturing Technology Management. Vol. 19, Issue 8, pp. 913-932.

Johnsen, T. E. 2009. Supplier involvement in new product development and innovation: Taking stock and looking to the future. Journal of Purchasing and Supply Management. Vol. 15, Issue 3, pp. 187-197.

Johnsen, T. E. 2011. Supply network delegation and intervention strategies during supplier involvement in new product development. International Journal of Operations & Production Management. Vol. 31, Issue 6, pp. 686-708.

Johnsen, T. E., & Ford, D. 2007. Customer approaches to product development with suppliers. Industrial Marketing Management. Vol. 36, Issue 3, pp. 300-308.

Johnston, D. A., McCutcheon, D. M., Stuart, F. I., & Kerwood, H. 2004. Effects of supplier trust on performance of cooperative supplier relationships. Journal of operations Management. Vol. 22, Issue 1, pp. 23-38.

Kamath R. R. & Liker, J. K. 1994 A Second Look at Japanese Product Development. Harvard Business Review. October-November, pp. 154-170.

Kato, Y. 1993. Target costing support systems: lessons from leading Japanese companies. Management Accounting Research. Vol. 4, Issue 1, pp. 33-47.

Koufteros, X., Vonderembse, M., & Jayaram, J. 2005. Internal and external integration for product development: the contingency effects of uncertainty, equivocality, and platform strategy. Decision Sciences. Vol. 36, Issue 1, pp. 97-133.

Kraljic, P. 1983. Purchasing must become supply management. Harvard business review. Vol. 61, Issue 5, pp. 109-117.

Krishnan, V., & Ulrich, K. T. 2001. Product development decisions: A review of the literature. Management science. Vol. 47, Issue 1, pp. 1-21.

Lakemond, N., Berggren, C., & Weele, A. 2006. Coordinating supplier involvement in product development projects: a differentiated coordination typology. R&D Management. Vol. 36, Issue 1, pp. 55-66.

Langner, B., & Seidel, V. P. 2009. Collaborative concept development using supplier competitions: Insights from the automotive industry. Journal of Engineering and Technology Management. Vol. 26, Issue 1, pp. 1-14.

Laseter, T. M., & Ramdas, K. 2002. Product types and supplier roles in product development: an exploratory analysis. Engineering Management, IEEE Transactions. Vol. 49, Issue 2, pp. 107-118.

Le Dain, M. A., Calvi, R., & Cheriti, S. 2010. Developing an approach for design-or-buy-design decision-making. Journal of Purchasing and Supply Management. Vol. 16, Issue 2, pp. 77-87.

Le Dain, M. A., Calvi, R., & Cheriti, S. 2011. Measuring supplier performance in collaborative design: proposition of a framework. R&D Management. Vol. 41, Issue 1, pp. 61-79.

McCutcheon, D. M., Grant, R. A., & Hartley, J. 1997. Determinants of new product designers' satisfaction with suppliers' contributions. Journal of Engineering and Technology Management. Vol. 14, Issue 3, pp. 273-290.

McGinnis, M. A., & Vallopra, R. M. 1999. Purchasing and supplier involvement in process improvement: a source of competitive advantage. Journal of Supply Chain Management. Vol. 35, Issue 3, pp. 42-50.

McIvor, R., Humphreys, P., & Cadden, T. 2006. Supplier involvement in product development in the electronics industry: a case study. Journal of Engineering and Technology Management. Vol. 23, Issue 4, pp. 374-397.

Melander, L. 2014. Supplier selection under technological uncertainty in new product development projects. International Journal of Technology Intelligence and Planning. Vol. 10, Issue 2, pp. 108-128.

Melander, L., & Lakemond, N. 2014. Variation of purchasing's involvement: case studies of supplier collaborations in new product development. International Journal of Procurement Management. Vol. 7, Issue 1, pp. 103-118.

Melander, L., & Lakemond, N. 2015. Governance of supplier collaboration in technologically uncertain NPD projects. Industrial Marketing Management. Vol. 49, pp. 116-127.

Melander, L., & Tell, F. 2014. Uncertainty in collaborative NPD: Effects on the selection of technology and supplier. Journal of Engineering and Technology Management. Vol. 31, pp. 103-119.

Mikkola, J. H. 2003. Modularity, component outsourcing, and inter-firm learning. R&D Management. Vol. 33, Issue 4, pp. 439-454.

Mikkola, J. H., & Skjoett-Larsen, T. 2003. Early supplier involvement: implications for new product development outsourcing and supplier-buyer interdependence. Global Journal of Flexible Systems Management. Vol. 4, Issue 4, pp. 31-41.

Monczka R.M., Handfield R.B., Scannel T.V., Ragatz G.L., Frayer D.J., 2000, New Product Development: Strategies for Supplier Integration, 1st edition, Amer Society for Quality, 209 p.

Monczka, R. M., Trent, R. J., & Callahan, T. J. 1993. Supply base strategies to maximize supplier performance. International Journal of Physical Distribution & Logistics Management. Vol. 23, Issue 4, pp. 42-54.

Möller, K. K., & Törrönen, P. 2003. Business suppliers' value creation potential: A capability-based analysis. Industrial Marketing Management. Vol. 32, Issue 2, pp. 109-118.

O'Neal, C. 1993. Concurrent engineering with early supplier involvement: a crossfunctional challenge. International Journal of Purchasing and Materials Management. Vol. 29, Issue 1, pp. 2-9.

Parker, D. B., Zsidisin, G. A., & Ragatz, G. L. 2008. Timing and extent of supplier integration in new product development: a contingency approach. Journal of Supply Chain Management. Vol. 44, Issue 1, pp. 71-83.

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. 2003. A Model of Supplier Integration into New Product Development*. Journal of Product Innovation Management. Vol. 20, Issue 4, pp. 284-299.

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. 2005. Supplier integration into new product development: coordinating product, process and supply chain design. Journal of operations management. Vol. 23, Issue 3, pp. 371-388.

Petroni, A., & Panciroli, B. 2002. Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry. European Journal of Purchasing & Supply Management. Vol. 8, Issue 3, pp. 135-149.

Prahalad, C.K. & Hamel, G. 1990. The Core Competence of the Corporation. Harvard Business Review. Vol. 68, Issue 3, pp. 79-91.

Primo, M. A., & Amundson, S. D. 2002. An exploratory study of the effects of supplier relationships on new product development outcomes. Journal of Operations management. Vol. 20, Issue 1, pp. 33-52.

Ragatz, G. L., Handfield, R. B., & Petersen, K. J. 2002. Benefits associated with supplier integration into new product development under conditions of technology uncertainty. Journal of Business Research. Vol. 55, Issue 5, pp. 389-400.

Ragatz, G. L., Handfield, R. B., & Scannell, T. V. 1997. Success factors for integrating suppliers into new product development. Journal of product innovation management. Vol. 14, Issue 3, pp. 190-202.

Rouibah, K., & Caskey, K. R. 2005. Managing concurrent engineering with early supplier involvement: a case study. International Journal of Computer Integrated Manufacturing. Vol. 18, Issue 6, pp. 509-521.

Sarkar, A., & Mohapatra, P. K. 2006. Evaluation of supplier capability and performance: A method for supply base reduction. Journal of Purchasing and Supply Management. Vol. 12, Issue 3, pp. 148-163.

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research methods for Business Students, 5th edition. Prentice Hall. 614 p.

Schiele, H. 2006. How to distinguish innovative suppliers? Identifying innovative suppliers as new task for purchasing. Industrial Marketing Management. Vol. 35, Issue 8, pp. 925-935.

Schiele, H. 2010. Early supplier integration: the dual role of purchasing in new product development. R&D Management. Vol. 40, Issue 2, pp. 138-153.

Schiele, H. 2012. Accessing supplier innovation by being their preferred customer. Research-Technology Management. Vol. 55, Issue 1, pp. 44-50.

Smith, M. E., & Zsidisin, G. A. 2002. Early supplier involvement at MRD. Practix: Best Practices in Purchasing and Supply Chain Management. Vol. 5, Issue 4, pp. 1-5.

Swink, M. L., & Mabert, V. A. 2000. Product development partnerships: Balancing the needs of OEMs and suppliers. Business Horizons. Vol. 43, Issue 3, pp. 59-68.

Takeishi, A. 2001. Bridging inter-and intra-firm boundaries: management of supplier involvement in automobile product development. Strategic Management Journal. Vol. 22, Issue 5, pp. 403-433.

Terwiesch, C., Loch, C. H., & Meyer, A. D. 2002. Exchanging preliminary information in concurrent engineering: Alternative coordination strategies. Organization Science. Vol. 13, Issue 4, pp. 402-419.

Trent, R. J. 2007. Strategic supply management: creating the next source of competitive advantage. J. Ross Publishing. 303 p.

Trochim, W. 2000. The Research Methods Knowledge Base, 2nd Edition. Atomic Dog Publishing, Cincinnati, OH.

Ulrich, K. 1995. The role of product architecture in the manufacturing firm. Research policy. Vol. 24, Issue 3, pp. 419-440.

Ulrich, K. & Eppinger, S. 2008. Product design and development. (4th ed.), Boston, McGraw-Hill. 368 p.

Van der Valk, W., & Wynstra, F. 2005. Supplier involvement in new product development in the food industry. Industrial Marketing Management. Vol. 34, Issue 7, pp. 681-694.

Van Echtelt, F. E., Wynstra, F., Van Weele, A. J., & Duysters, G. 2008. Managing Supplier Involvement in New Product Development: A Multiple-Case Study*. Journal of Product Innovation Management. Vol. 25, Issue 2, pp. 180-201.

Wagner, S. M. 2003. Intensity and managerial scope of supplier integration. Journal of Supply Chain Management. Vol. 39, Issue 3, pp. 4-15.

Wagner, S. M., & Hoegl, M. 2006. Involving suppliers in product development: Insights from R&D directors and project managers. Industrial marketing management. Vol. 35, Issue 8, pp. 936-943.

Walter, A. 2003. Relationship-specific factors influencing supplier involvement in customer new product development. Journal of Business Research. Vol. 56, Issue 9, pp. 721-733.

Wasti, S. N., & Liker, J. K. 1997. Risky business or competitive power? Supplier involvement in Japanese product design. Journal of Product Innovation Management. Vol. 14, Issue 5, pp. 337-355.

Wynstra, F., Axelsson, B., & Van Weele, A. 2000. Driving and enabling factors for purchasing involvement in product development. European Journal of Purchasing & Supply Management. Vol. 6, Issue 2, pp. 129-141.

Wynstra, F., & Ten Pierick, E. 2000. Managing supplier involvement in new product development: a portfolio approach. European Journal of Purchasing & Supply Management. Vol. 6, Issue 1, pp. 49-57.

Wynstra, F., van Weele, A., Axelsson, B. 1999. Purchasing involvement in product development: a framework. European Journal of Purchasing & Supply Management. Vol. 5, Issues 3–4, pp. 129-141.

Wynstra, F., Van Weele, A., & Weggemann, M. 2001. Managing supplier involvement in product development: Three critical issues. European Management Journal. Vol. 19, Issue 2, pp. 157-167.

Wynstra, F., Weggeman, M., & Van Weele, A. 2003. Exploring purchasing integration in product development. Industrial Marketing Management. Vol. 32, Issue 1, pp. 69-83.

Yassine, A., & Braha, D. 2003. Complex concurrent engineering and the design structure matrix method. Concurrent Engineering. Vol. 11, Issue 3, pp. 165-176.

Yoshikawa, T., Innes, J., & Mitchell, F. 1994. Applying functional cost analysis in a manufacturing environment. International Journal of Production Economics. Vol. 36, Issue 1, pp. 53-64.

Zsidisin, G. A., & Smith, M. E. 2005. Managing supply risk with early supplier involvement: a case study and research propositions. Journal of supply chain management. Vol. 41, Issue 4, pp. 44-57.

APPENDICES (3 pieces)

APPENDIX 1: List of interviewees

APPENDIX 2: List of participants in the workshop with suppliers

APPENDIX 3: ESI considerations based on literature review

APPENDIX 1: List of interviewees

Case company interviewees (title):

- Sourcing project manager #1
- Sourcing project manager #2
- Sourcing project manager #3
- Component manager (mechanics)
- Category manager (mechanics)
- Supplier quality manager
- Application manager (mechanics)
- R&D project manager
- Mechanical engineer x3
- Senior mechanical engineer x3

Supplier interviewees (type of technology):

1. Machining #1
2. Machining #2
3. Sheet metals #1
4. Sheet metals #2
5. Packaging
6. Enclosures (Sheet metal)
7. Plastics
8. Cables and harnesses
9. EMS #1
10. EMS #2
11. EMS #3

APPENDIX 2: List of participants in the workshop with suppliers

Supplier technology	Supplier participants	Case company participants
EMS	Manager, engineering services Global account manager Project manager	Development manager (electronics) Sourcing project manager Senior electronics engineer Thesis worker
Cables & harnesses	Managing director Area manager Sales manager	Sourcing development manager Electronics engineer R&D project manager
Machining	Managing director Sales engineer Application manager	Sourcing project manager Senior mechanical engineer Development manager (mechanics)
Plastics	CEO Sales manager	Senior mechanical engineer Category manager (mechanics)

APPENDIX 3: ESI considerations based on literature review

Type of technology	Key driving factor and goal	Extent / activities	Supplier status and type	Communication & coordination	Business model
Mechanics, electronics, cables & harnesses Generic or special Single part or assembly	Design risks Schedule risks Uncertainty Cost criticality Short term efficiency Long term learning	White box: consultation Grey box: joint design efforts Black box: supplier main design responsibility	Strategic Preferred Approved / new Generic contractor or specialized supplier	Open / limited, frequency of communication What information is exchanged and among whom Direct ad-hoc Integrated Decoupled	Transactional, pay for input Relational/partnership, business motivation